JANUARY, 1961
Vol. 15, No. 1

FT food technology

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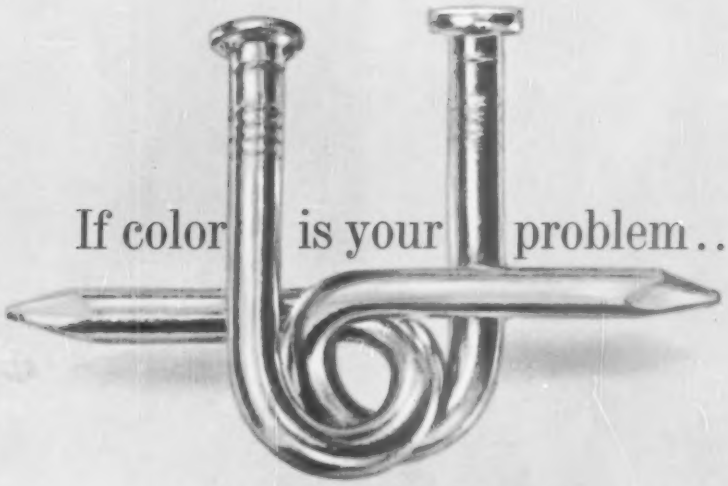

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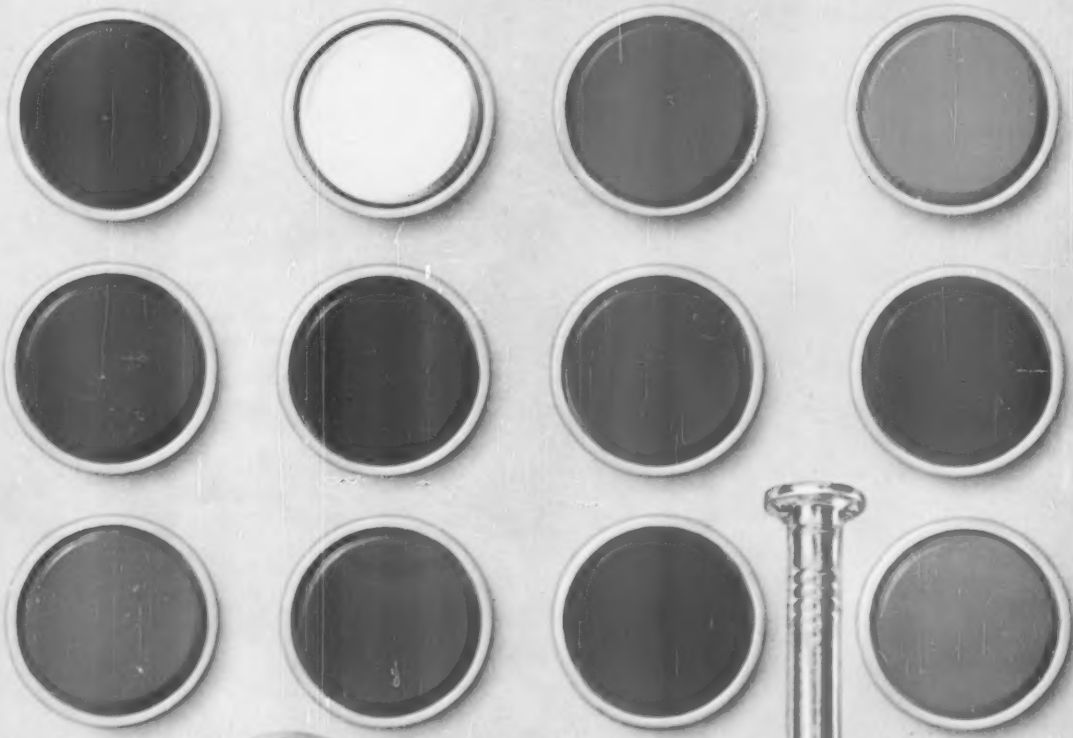

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FT food technology

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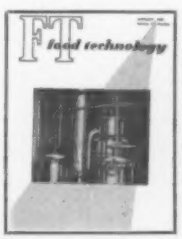

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Dr. Peterson Retires as Editor of IFT Publications

Dr. Imri J. Hutchings
President, Institute of Food Technologists

It is with heartfelt pleasure that as President of the IFT, I am in a position to acknowledge the outstanding efforts of Dr. Martin S. Peterson as Editor of Institute publications.

Although the Institute has grown both in size and prestige since "Dr. Pete" was officially appointed Editor on June 8, 1952, it is my feeling that the standards of editorial excellence maintained are partially responsible for a "faster than normal" rate of growth. Through efforts directed toward serving the Institute, as well as many thousands of other interested personnel in the food industry, FOOD TECHNOLOGY has become an accepted part of the vocabulary of Food Technologists.

Martin S. Peterson

Martin Severin Peterson was born April 21, 1897, at Chemawa Indian Academy near Salem, Oregon. He attended public schools in McMinnville, Oregon, until graduation from high school, and then enrolled at Reed College, Portland, where he received an A.B. Between 1926 and 1945, Dr. Peterson taught at the University of Nebraska, and completed requirements for an M.S. and Ph.D. in English in 1932. He is a member of the honorary societies, Phi Tau Sigma and Sigma Upsilon.

It may be of interest to note that while attending Reed College, he played championship handball against the man who is the present Senator from Illinois, Paul Howard Douglas—and beat him!

Between 1946 and 1947, he was associated with the Western Regional Laboratory, and from then to the present his association has been with the QMF&CI in Chicago.

Author of three books: "Joaquin Miller, Literary Frontiersman," "Using Better English," and "Business Letters and Reports," Dr. Peterson has found time to increase the number of technical pages in FOOD TECHNOLOGY from 484 in 1952 to 742 in 1959 and 670 in 1960. Such an increase, in addition to maintaining editorial excellence, is certainly a tribute to Dr. Peterson.

Behind the scenes contributing many hours of detailed work for each issue of both our journals, is Wilma Peterson. It is my pleasure to express gratitude to her, for her untiring work on behalf of the Institute.

While retiring as Editor of Institute publications, Dr. Peterson will retain his position as Chief of the Technical Services Office, Quartermaster Food and Container Institute of the Armed Forces. In addition, he has another book in press (Reinhold) which will be published this spring.

Again I express tribute to our former Editor, and offer best wishes to his successor, Dr. George F. Stewart, who commenced his duties with this issue.

Announcement to Scholars and Would-be Scholars

Applications for IFT administered Fellowships, Scholarships and Awards are now being accepted by: Executive Secretary, IFT, 176 W. Adams St., Chicago 3, Illinois.

Each year the IFT administers over $22,000 for educational purposes. Eligibility and prerequisites for these thirteen awards in the area of food technology, effective during the 1961-62 school year, are as follows:

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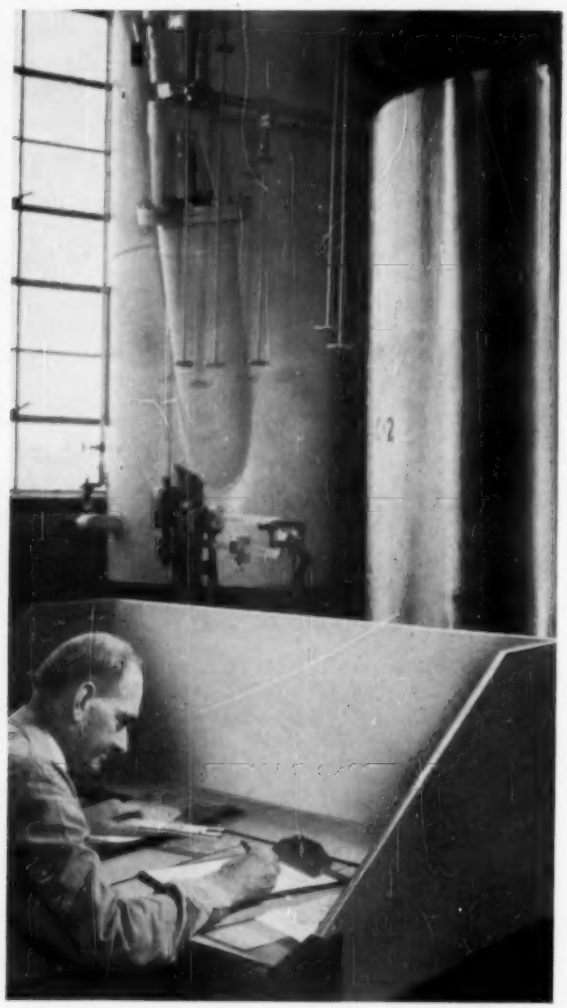
Presently under consideration are ten $300 undergraduate scholarships. Further details about them will be published in a future issue of FOOD TECHNOLOGY.

Deadline for receipt of applications and the accompanying photographs and letters of recommendation, is March 1st, 1961. Send all requests for applications, and completed applications, to: Executive Secretary, Institute of Food Technologists, 176 West Adams Street, Chicago 3, Illinois.



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Flavor Nomenclature Committee in Action

For some time now, university and industry workers have been concerned with the general lack of agreement among food scientists as to the meaning and use of specific flavor terms and the need for a "language of flavor." There are far too few descriptive terms germane to flavor. A great part of the description used is based entirely upon simile, "it tastes like . . . , or it smells like . . . " Thus there really is no language of flavor.

In order to take some remedial action in this regard, a Flavor Nomenclature Committee (FNC) was formed by several interested members of the Institute of Food Technologists to examine the current status of flavor terminology, conduct experiments, and create a systematic language of flavor suitable for the use of scientists everywhere. The ultimate goal is to produce a compendium of flavor terms that will provide a means for rapid and accurate data transfer for those persons interested in foods.

In the selection of the Committee, it was felt that it would be desirable to have members from all walks of life with one common interest among them, that is, food flavor problems. Persons were selected from the fields of industry, education, and government. Members of the committee are as follows:

Professor Maynard A. Amerine
Department of Viticulture and Enology
University of California
Davis, California

Professor Richard A. Bernhard, Chairman
Department of Food Science and Technology
University of California
Davis, California

Dr. Joseph Corse
Fruit and Vegetable Laborat
United States Department of , ture
WURDD
Albany, California

Dr. Richard L. Hall
Director of Research and Development
McCormick and Company
Baltimore, Maryland

Professor Amihud Kramer
Department of Horticulture
University of Maryland
College Park, Maryland

Mr. Harvey K. Murer (Deceased)[a]
Director of Research
General Foods Corporation
Tarrytown, New York

Dr. Martin S. Peterson
QM Food and Container Institute
Chicago, Illinois

Dr. Andrew J. Sullivan
Flavor Biochemistry Research
Campbell Soup Company
Camden, New Jersey

[a] The Committee notes with deep regret that Mr. Murer was killed in an automobile accident last August.

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Mr. Chester A. Wood
William J. Stange Company
Chicago, Illinois

The Flavor Nomenclature Committee had its first meeting on Monday, May 16, 1960, during the IFT Annual Meeting in San Francisco, California. During this meeting, various aspects of the flavor nomenclature problem were discussed fully and a course of action to be followed for the future was determined with unanimous agreement among the ten members present.

A proposed study to be conducted by the Flavor Nomenclature Committee is as follows:

1. To devise a condensed list of descriptive terms that would describe oral sensations (such as pure taste and chemical sense, those compounds or sensations which affect free nerve endings on the tongue and nasal passage) and tactile responses.

2. To prepare samples to be evaluated employing these descriptive flavor terms.

3. To evaluate the results of such findings and to make them known to the IFT membership.

In preparing the list of descriptive flavor terms, it was decided to use the simplest terms which were available and in common usage throughout the United States. Such terms as bitter, flat, metallic, moldy, musty, sweet, sour, salty, rubbery, rancid, soapy, woody, yeasty were included as typical descriptive terms in current use. It has been decided to avoid the use of such terms as aromatic, clean, clear, green, pungent as being either too general, not characteristic enough, or duplicative of the above terms. Such a list has now been prepared and distributed to the members of the Flavor Nomenclature Committee.

The Committee decided that a common food to be evaluated should be readily available, should withstand rough treatment without changing or altering its flavor too greatly, and could be distributed to all members of the committee for evaluation in their own laboratories or offices. Tomato juice was unanimously selected as this material. In addition, a sample of a pure organic compound was to be evaluated and this, too, was to have the above-mentioned characteristics.

Samples of tomato juice and the unknown organic compound were mailed by the Chairman from Davis, California, to each member of the committee. The tomato juice was to be evaluated by taste (oral sensation), tactile response, and odor response; the pure organic compound was to be measured by smelling only. The intensity of each of the descriptive terms was to be rated on a scale of 1–3. Thus, one may evaluate tomato juice as being salty, with an intensity factor of 2, and/or flat with an intensity factor of 1, metallic, intensity factor of 2, and so forth. The experiment is still in progress, and the results will be made known to the IFT membership as soon as possible.

The Chairman of the FNC felt it was desirable to inform the members of the IFT of its actions and also to allow the members to know that this group is working in their behalf to help resolve a most serious problem. At the next FNC meeting, tentatively scheduled for mid-winter, it will examine the results of this particular test and try to determine if the approach can be considered satisfactory. In the event it is unsatisfactory, proceedings to develop another system of terminology will be initiated.

RICHARD A. BERNHARD

FUTURE MEETINGS FOR FOOD TECHNOLOGISTS

1961	
February 2-3	Statistical Quality Control and Instrumentation Workshop for the Food Industry (co-sponsored by the Institute of Food Technologists, Western New York Section, and N.C.A.) Cornell University, Ithaca, New York.
February 28 –March 1	Ninth Annual National Dairy Engineering Conference (co-sponsored by the Department of Agricultural Engineering and the Department of Food Science, Michigan State University, and the National Association of Dairy Equipment Manufacturers) Michigan State University, East Lansing
April 4-6	Fifteenth Annual Meeting of the Research and Development Associates, Food and Container Institute, Hotel John Marshall, Richmond, Virginia
April 11-12	Food Engineering Conference, Michigan State University, East Lansing, Michigan. (For information write to Continuing Education Service, Michigan State University, East Lansing)
May 7-11	**Twenty-first Annual Meeting of the Institute of Food Technologists, Hotel Statler, New York, New York**
May 15-18	Fourth International Congress on Canned Foods, Berlin, Germany (for information address M. Henri Cheftel, 71, Avenue Edouard Vaillant, Billancourt (Seine), France.
1962	
June 10–14	**Twenty-second Annual Meeting of the Institute of Food Technologists, Fontainebleau Hotel, Eden Roc Hotel, Miami Beach, Florida**
1963	
May 19–23	**Twenty-third Annual Meeting of the Institute of Food Technologists, Pantlind Hotel, Civic Auditorium, Grand Rapids, Michigan**

An open invitation is extended to readers of FOOD TECHNOLOGY to send in to the Editorial Office, P. O. Box 164, Davis, California, notices of annual or national meetings of interest to food technologists.

The Role of Convenience in Food Selection[a]

R. L. Baker [b]
Department of Agricultural Economics and Rural Sociology, The Pennsylvania State University

SUMMARY

Convenience plays an important role in food selection. Its relative importance, however, is dependent on the strengths of other parts of the value system. Since not all consumers are precisely alike, it is quite apparent that these other pulls must be considered if we are to maximize returns from food marketing.

DECISIONS ARE MADE on the basis of values resulting from experiences or expectations of the decision maker. The emotional determinants of choice making, Nolan (1953) indicated, are attitudes, values, and preferences. These concepts provide the frame of reference that permits choice making without considering the multitude of possible alternatives for the many decisions that must be made each day. The three concepts interact with one another. Values can either control attitudes or preferences or be developed from them, but values prescribe the desired action under a particular situation.

John (1956) indicated that six kinds of values are associated with food selection: functional, economic, status, self-esteem, esthetic and sentimental. This paper emphasizes the first aspect—functional value. That value sets the standard of performance of a product in term of socially defined criteria.

These criteria may have either a biogenic or psychogenic base, but decisions to purchase are likely to result from combinations of the two kinds of need (Bayton, 1958).

Thus, functional values as used in this paper are determined from a broader, and perhaps less precise, base than functional properties as defined by the food technologist. Values may emanate from society, the community, one's peers, one's family, or the individual. Functional properties are strictly biogenic, emanating from the product itself or the vehicle employed in making the product available to the user. The effect of these properties on choice, however, stems from biogenic and/or psychogenic needs.

Convenience is one aspect of functional value. This functional value has become so important in our technically oriented society that homemakers no longer

[a] Presented at the Institute of Food Technologists, Twentieth Annual Meeting, San Francisco, California, May 16, 1960.

[b] The assistance of T. M. Brooks, M. E. John, and H. B. Bylund in preparing this paper is greatly appreciated.

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rationalize the use of convenience items. In other words, a convenience item is selected without having in mind an alternative use for the time or effort saved. In fact, in certain groups, one might select a convenience item in order to avoid ridicule by one's peers.

Convenience takes many forms. Decisive factors in selection may be such functional properties as the ease of opening, handling, or storing a package. For instance, in a study of consumers in Harrisburg, Pennsylvania, the following question was raised: "Here is a picture of two packages of cereal. The cereal in the cellophane bag costs 21 cents and that in the box 25 cents. Which would you buy?" Of those interviewed 86% selected the box, 13% the cello bag, and 1% had no preference. The consumers were then asked: "What is there about ..... that makes you prefer it?" Of those selecting the box, three-fourths justified their selection on the basis of convenience factors, which included easier to handle, easier to open, easier to store, or the package isn't likely to split or fall apart. Only about one-fifth of the group justified their selection of the box on the basis of product factors, which would generally fall into a better-quality category with the most often mentioned specific factor being that the product is likely to be fresher.

Of those who selected the "cello" bag, more than four-fifths justified their selection on an economy basis, and only 4% on factors that could be called convenience reasons.

Although the consumers were given only one of the variables (price) they needed in order to determine the relative economy of the two packages, only 4% of those interviewed asked about the quantity of cereal in each package (18% of those selecting the bag, and only 2% of those selecting the box). Consumers with an annual take-home pay of $8,000 or more and those 60 years old and over were more likely to select the box than consumers in other income or age groups.

Although a major share of the consumer market in this instance would go to the cereal packaged in the box, there remains a necessity for differentiating the market between the economy-minded and the convenience-minded.

Another economy-convenience dichotomy can be illustrated by the selection of brands of non-fat dry milk. Obviously, there are both economy and convenience pulls in selecting non-fat dry milk compared to other kinds of milk. However, in this case, economy is a strong reason for selecting the product. Once the decision has been made to use the product, the decision within the product group (among the brands available) is not necessarily made on an economic basis. The Harrisburg consumer group was confronted with six brands of non-fat dry milk available in Harrisburg stores: 3 nationally advertised brands, 2 private brands, and 1 non-private brand not widely advertised. The recommended quart equivalent of the manufacturer and the total price for each package of milk were given with the picture of each brand. Only consumers who reported using non-fat dry milk were asked to make a choice.

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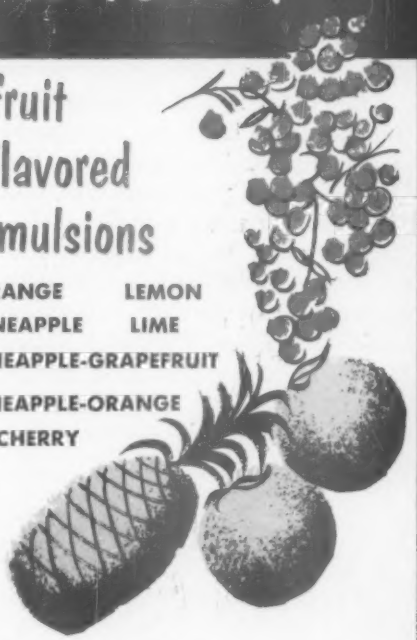
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cost per quart was 6½–9 cents. About ⅗ of the interviewees selected the brand that cost about 8½ cents a quart. The brand with the lowest cost per quart was selected by about ¼ of the consumers. The rationalization for selection of this brand, low cost, was the only one of the group in which economy was given as the major reason for selection. The one brand in which convenience stood out as a selection reason was sold in a package containing 10 one-quart-size envelopes. The major reason given for selecting this brand was convenience of measuring. However, the brand preferred by the majority was one of the two brands that at that time featured instant reconstitution. In addition to instant reconstitution, the most preferred brand had a pour spout on the package. Specific convenience factors such as easier to measure, easier to get from container, and easier to mix were given for selection of this brand. But a majority of the consumers gave as their first reason for selecting any of the nationally advertised brands, "We prefer ..... brand."

Apparently, an important factor in determining whether a particular selection will be made is the consumer's belief in her ability to make the right decision. About two-thirds of those interviewed reported that they generally buy apples loose. A similar proportion indicated they bought potatoes already packaged. The most important reasons for buying either apples or potatoes packaged were: "saves time in the store," and "easy to handle." For those who generally bought potatoes or apples loose, the most important reasons given were: "we prefer to make our own selection," or "we get better-quality products that way." Nearly one-fifth of the consumers indicated that they purchased apples or potatoes either loose or packaged because there was no alternative at the place where they generally bought the product.

Two important points appear to be brought out by these differences in preferences. One is that the consumers believed that there were enough differences in product attributes that they could afford to take more time in selecting apples than in selecting potatoes. The other is the possibility of increasing sales by differentiating products by packaging.

The latter point has been substantiated in many experimentally designed store studies. For example, Smith (1955) reported that the addition to the bulk display of packaged apples in 3-lb or 5-lb units increased sales significantly over bulk apples alone.

The addition of variable sizes of packages of apples to the bulk display also increased sales more than the addition of 5-lb packages only.

In some instances, there may be a conflict between a functional value like convenience and a value like self-esteem. One of the important satisfactions in homemaking is the self-esteem derived from creativity. This creativity may be an important part of meal preparation and serving. A major factor in the decision of cake mix manufacturers to use no eggs in most cake mixes was the notion that breaking the egg into the mix adds a feeling of creativity, thereby increasing the homemaker's self-esteem. About one-fourth of the interviewees in the present study indi-

(Continued on page 17 following technical section)

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BOOKS

FOOD CHEMISTRY. Lillian H. Meyer. xiv—385 pages. Reinhold Publishing Corp., College Textbook Department, 430 Park Avenue, New York. 1960. College ed. $6.75. Trade ed. $8.10.

The problem: how does an author integrate the sciences of biology, bacteriology, mycology, chemistry, chemical engineering, and physics into one cohesive whole and then proceed to write a short text book on food chemistry making use of this vast amount of knowledge? Professor Meyer has tackled this problem in her book and carried it off rather well. She has managed to keep the contents to a comfortable 350 pages of text and the publishers have been able to keep the price within reason so that the average undergraduate can buy the book without wincing.

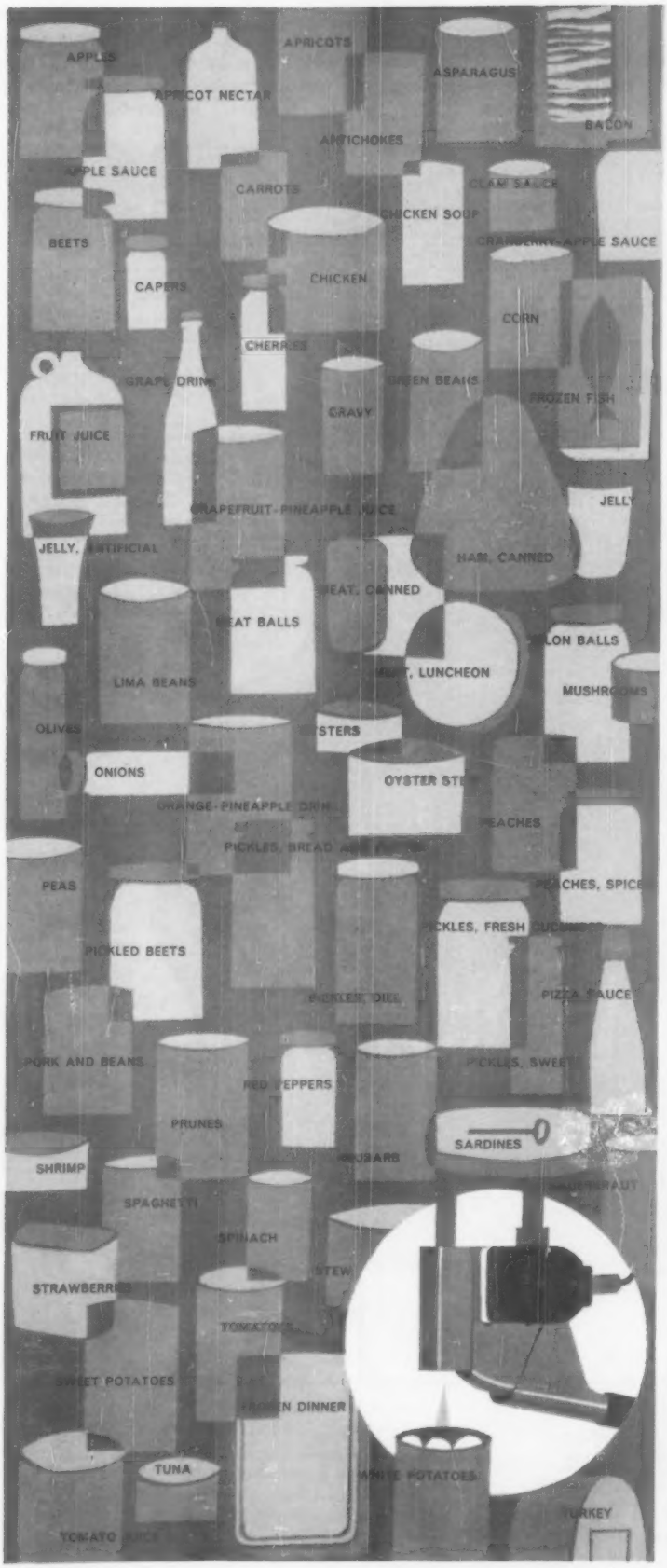
The text begins with a short historical summary of food chemistry and its development. There is a rather extensive chapter on fats and other lipids which includes a long discussion of the technology of individual fat products. There are chapters on carbohydrates, proteins in foods, flavor and aroma of foods, meat and meat products, vegetables and fruits, milk and milk products, cereals, and a supplemental chapter on food additives. There is also a convenient appendix which lists permitted additives as of January, 1960.

The primary emphasis of the book is on the composition of foods and the changes that occur when they are subjected to processing. Professor Meyer has had to choose the difficult path of selecting material and supposing that the student reader has had sufficient background to understand most of the textual matter. She has managed to tight-rope this difficult line well. Food Chemistry contains a great many fine illustrations and a large number of tables which are illustrative of the textual material. In general the format is good. Unfortunately, there are several errors in the chemical formulas. For example, in the formation of glucosazone on page 101.

One of the high spots in the text, to this reviewer's way of thinking, is the author's neat and pungent discussion of the use of nuclear magnetic resonance in the determination of moisture in food samples. One of the low spots appears on page 161 in which the author discusses her personal preference for the use of monosodium glutamate. Is the student really interested in whether monosodium glutamate is highly objectionable to Professor Meyer?

In general, the author has done a splendid job in providing the undergraduate with a well organized, descriptive text book of food chemistry.

RICHARD A. BERNHARD



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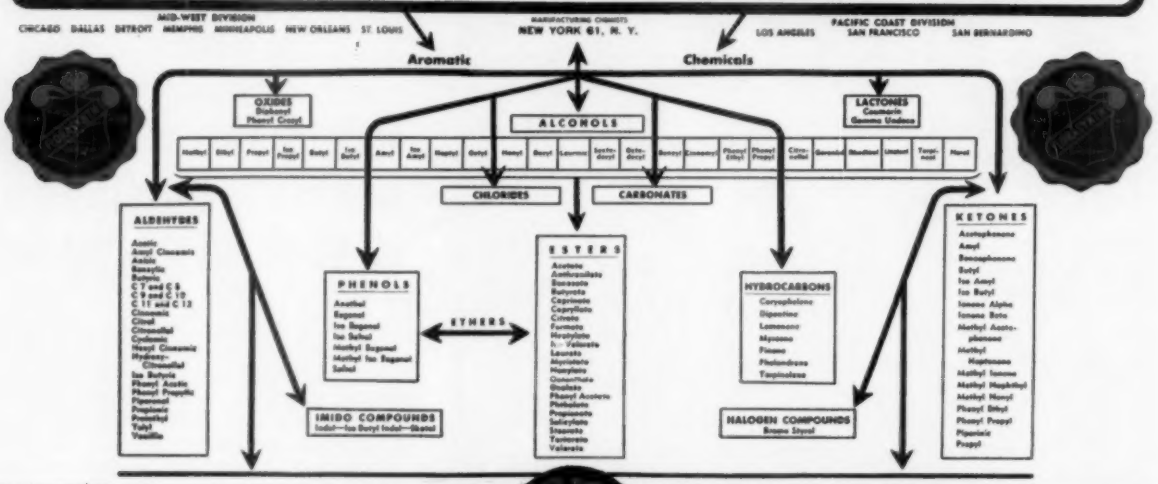

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Maple Sirup. XVII.

Prevention of Mold and Yeast Growth in Maple Sirup by Chemical Inhibitors

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Eastern Regional Research Laboratory*, Philadelphia 18, Pennsylvania

(Manuscript received July 9, 1960)

SUMMARY

Growth inhibition of mold and yeast inocula in maple sirup was studied. Low levels of esters of para-hydroxybenzoic acid (PHBA) were found to be more effective than conventional mold inhibitors (proprionate, sorbate, benzoate). Sodium propyl PHBA at a concentration of less than 0.02% was inhibitory to the growth of four yeast and eight mold strains inocula in maple sirup.

In the process of sirup making, sap is converted to sirup by lengthy heat evaporation to remove the required amount of water. The temperature of the resulting sirup is about 217–220° F during the terminal stage of heating. All organisms initially present in the sap are destroyed during this heating process. However, when sirup is allowed to cool excessively before being packaged, contamination may enter from the air or from equipment. "Hot canning," that is, packaging maple sirup while its temperature is near 200° F, has been recommended for preventing microbial growth *(6, 7, 19)*.

Microbial contaminants are introduced into sirup during packaging in the sugar house or during home use of small, commercial-size containers. Spoilage of maple sirup during storage of bulk stock or during consumer use of smaller containers is caused primarily by mold growth and, less frequently, by yeasts *(5, 7, 8)*. The high osmotic pressure of standard density maple sirup prevents bacterial spoilage. However, a few molds and yeasts can survive but will not grow except where the sirup becomes diluted.

Sirups in bulk containers or in small packages usually have a free head space above the sirup. Stored sirup is usually subjected to slight changes in temperatures. During the warm cycle, moisture from the sirup distills into the head space, and this moisture condenses out as free droplets of water during the cold cycle. These droplets eventually collect on the sirup surface and dilute it.

Use of chemical inhibitors for the preservation of foods is a practice of long standing. In the United States those commonly used are: sorbate, propionate and benzoate. Recently, the esters of para-hydroxy benzoate (PHBA) have been recommended *(2, 13)*. These esters have been employed for a number of years in cosmetics and pharmaceutical preparations *(4, 11, 12, 16)* and in foods in several European countries *(9, 11, 16)*.

PHBA esters are quite soluble in aqueous and organic media *(2)* making them applicable to a wide variety of foods. Sokol *(18)* has reported that effectiveness of PHBA esters decreases as the length of the chain of the alkyl ester increases. Several investigators *(2, 14, 15, 16)* have reported that mixtures of the esters enhance their preservative effect, which has been termed by Littlejohn and Husa *(11)* a potentizing action. Because of their effective inhibition of molds, yeasts and bacteria, at low concentrations, their low toxicity *(4, 10, 13, 18)*, and their lack of flavor, odor and color *(2, 4)* the esters of PHBA have been called the ideal preservative *(18)*.

The purpose of this study was to investigate the effectiveness of chemical inhibitors, especially the PHBA esters, for preventing mold and yeast growth in pure maple sirup.

MATERIALS AND METHODS

Organisms. The mold and yeast strains used in this study are shown in Table 1. Stock cultures were maintained on the modified dextrose agar medium of Sheneman and Costilow *(17)*.

Inocula. Plates of dextrose agar medium were seeded with suspensions of the test organisms and incubated at 80° F. Yeast cells were harvested after one week of incubation; the mold strains were harvested after two weeks. Surface growth was removed by gently flushing with distilled water and scraping lightly with a stainless steel rod. Cell concentrations in stock

TABLE 1

Organisms employed in study of maple sirup spoilage

Organism	Strain	Source and/or donor
Molds:		
Aspergillus flavus	ALCA-13	T. C. Cordon, Hide and Leather culture collection, EURDD
Aspergillus niger	2270	Maple sap, Maple Investigations culture collection, EURDD
Fusarium oxysporum	R-56	T. C. Cordon
Fusarium sp.	FBM-16	Maple sap, R. N. Costilow, Michigan State University
Mucor sp.	NG-12	T. C. Cordon
Mucor sp.	CZ-48	T. C. Cordon
Penicillium oxalicum	Pen. ox.	T. C. Cordon
Penicillium sp.	NG-1	T. C. Cordon
Penicillium sp.	NG-2	T. C. Cordon
Rhizopus oryzae	NRRL-395	T. C. Cordon
Rhizopus oryzae	NRRL-2004	T. C. Cordon
Rhizopus sp.	MX-82	T. C. Cordon
Yeasts:		
Cryptococcus albidus	496	Maple sirup, Maple Investigations culture collection, EURDD
Cryptococcus sp.	FBY-62	Maple sap, R. N. Costilow
Rhodotorula glutinis	FBY-56	Maple sap, R. N. Costilow
Unclassified	5Y	Maple sirup, Maple Investigations culture collection, EURDD
Unclassified	TY-2	Maple sirup, Maple Investigations culture collection, EURDD
Unclassified	Y-1000	Maple sirup, Maple Investigations culture collection, EURDD
Unclassified	Y-1049	Maple sirup, Maple Investigations culture collection, EURDD

* Eastern Utilization Research and Development Division, Agricutural Research Service, United States Department of Agriculture.

suspensions were estimated by conventional dilution and plating methods, using dextrose agar. Inocula containing desired numbers of cells were obtained by diluting the stock suspensions.

Inoculation of maple sirup. Appropriate amounts of the inhibitors were added, either directly or as small aliquots (1 ml or less) from stock solutions, to sterile four-ounce screw-cap bottles. U. S. Fancy grade pure maple sirup was heated to about 200° F and immediately added, in 100 ml aliquots, to the bottles containing the inhibitors. The caps were tightened, and the bottles allowed to remain undisturbed at room temperature for about one week to accomplish surface dilution *(19)*. Bottles were then inoculated with small aliquots (1 ml or less) of appropriate dilutions of stock suspensions of the yeast and mold strains. By running the liquid slowly down the inner neck of the bottle, inocula were run on the surface "layer" of the sirup. Caps were screwed tightly in place and all bottles incubated at 80° F for at least 2 months. The viability of each dilution of the suspensions was tested by inoculating untreated sirups and checking for growth.

Inhibitors.[b] Sodium benzoate,[c] sodium propionate,[d] potassium sorbate,[e] methyl para-hydroxybenzoate (PHBA),[f] sodium methyl PHBA,[f] propyl PHBA,[f] and sodium propyl PHBA.[f]

Estimation of inhibitory effect. Inhibition was evaluated by comparing the growth (or lack of it) on treated sirups with growth of the same organism on untreated (control) sirups. Where no growth was observed on the control sirup, no evaluation could be made of the inhibitor against the strain tested. Mold growth in the inoculated sirups was examined macroscopically. The presence of discrete colonies or of a surface mat by the end of the incubation period denoted a lack of inhibition. Yeast growth in the inoculated sirups was evaluated by streaking a small aliquot (about 0.2 ml) on surfaces of dextrose agar in petri plates. The appearance of at least 3 typical yeast colonies after one week of incubation was taken as the criterion for lack of inhibition. Inhibition is expressed (Tables 2, 3, and 4) as the lowest concentration of inhibitor preventing growth in 100 ml of inoculated maple sirup.

Estimation of flavor change in inhibitor-treated sirups. Flavors of inhibitor-treated sirups were compared with untreated (control) sirups and evaluated by a trained, five-member taste panel.

RESULTS

Preliminary screening of common mold inhibitors was made using potassium sorbate, sodium benzoate, and sodium propionate. Inocula of 130 cells of *Aspergillus niger*, strain 2270, were placed in bottles with 100 ml of sterile maple sirup containing 10, 20, 40, 60, 80, 100, 125, 150, 175, and 200 mg of inhibitor, respectively. Since growth was observed, after 2 weeks of incubation, in all inhibitor-treated sirups, a smaller inoculum containing only 13 cells was used in a second determination. Again, no inhibition was observed, even in sirup containing 200 mg of inhibitor per 100 ml.

The methyl and propyl esters of PHBA, as well as the sodium salts of these esters, were then tested as inhibitors of *A. niger*, strain 2270. The results observed after incubation for 69 days are shown in Table 2. While methyl PHBA inhibited growth of *A. niger*, propyl PHBA was inhibitory at the lowest level tested, 3.33 mg per 100 ml of sirup.

Since propyl PHBA was more effective than methyl PHBA as a mold inhibitor, further studies were carried out against 4 concentrations of *A. niger* using concentrations of 0.33, 1.67, 3.33, and 16.7 mg of propyl PHBA and sodium propyl PHBA per 100 ml of sirup. The results of this study, observed after incubation for 61 days, are shown in Table 3. The antifungal effectiveness of propyl PHBA and sodium propyl PHBA is apparent from the inhibition by low concentrations against heavy inocula. The sodium salt is slightly less effective than the acid form.

TABLE 2

Inhibition of growth of Aspergillus niger, strain 2270, in 100 ml of maple sirup containing esters of para-hydroxybenzoic acid (PHBA)

Inoculum Inhibitor	Lowest concentration of ester inhibiting growth, mg	
	20 cells	200 cells
Methyl PHBA	16.7	25
Sodium methyl PHBA	25	66
Propyl PHBA	3.33	3.33
Sodium propyl PHBA	3.33	3.33

Because of the ease of solubility of sodium propyl PHBA *(2, 4)*, it was used in subsequent experiments with other mold and yeast strains. Three levels of inocula (20, 200, and 2000 cells per bottle) were tested against four concentrations (0.33, 1.67, 3.33, and 16.7 mg) of sodium propyl PHBA per 100 ml of sirup. The test organisms included a variety of mold and yeast strains, several of which had been isolated from maple sap and sirup (Table 1). The effectiveness of sodium propyl PHBA as a growth inhibitor can be seen from the results (Table 4).

TABLE 3

Inhibition of growth of Aspergillus niger, strain 2270, in 100 ml of maple sirup containing propyl para-hydroxybenzoic acid (PHPA) and sodium propyl PHBA

Inoculum, cells	Lowest concentration of ester inhibiting growth, mg	
	Propyl PHBA	Sodium propyl PHBA
2000	3.33	16.7
200	3.33	3.33
20	1.67	3.33
2	1.67	1.67

Since 4 of 11 mold strains tested did not grow in untreated (control) sirups, they are not included in Table 4. These strains are R-56, FBM-16, CZ-48, and NG-2. Likewise, the following yeast strains did not grow in untreated (control) maple sirup and therefore are not shown in Table 4: FBY-62, FBY-56, and Y-1049.

The taste panel was unable to detect any flavor differences among samples of maple sirup either devoid of or containing the levels of sodium propyl PHBA employed in this investigation.

DISCUSSION

The yeasts and molds selected for this study consisted of isolates from maple sap and sirup, including some known to tolerate the osmotic pressure of standard density maple sirup. Also, other strains whose growth characteristics in maple sirup were not known were included to give a broader spectrum of representatives from these two groups of organisms. Data in Table 4 include only those strains which showed growth in the control (untreated) sirup since it is impossible to evaluate the effect of the inhibitor on those strains which did not grow. Several concentrations of inocula and inhibitors were tested to compare the effectiveness of the different inhibitors under various conditions.

Preliminary experiments showed that the PHBA esters, commonly called "parasepts" or "parabens"

[b] Mention of the names of companies supplying the inhibitors mentioned herein does not imply U. S. Department of Agriculture endorsement of their products over those of companies not named.

[c] Eastman Organic Chemicals, Rochester, New York.

[d] Nutritional Biochemicals Corporation, Cleveland, Ohio.

[e] Union Carbide Chemicals Company, New York, New York.

[f] Chemo Puro Manufacturing Corporation, Newark, New Jersey.

TABLE 4

Inhibition of mold and yeast growth in 100 ml of maple sirup containing sodium propyl para-hydroxybenzoic acid

Inoculum Organism	Lowest concentration inhibiting growth, mg		
	20 cells	200 cells	2000 cells
Molds:			
Aspergillus flavus, ALCA-13	3.33	16.7	16.7
Mucor sp., NG-12	3.33	16.7	16.7
Penicillium oxalicum, Pen. ox	1.67	1.67	3.33
Penicillium sp., NG-1	3.33	16.7	16.7
Rhizopus oryzae, NRRL-395	16.7	16.7	16.7
Rhizopus oryzae, NRRL-2004	3.32	16.7	16.7
Rhizopus sp., MX-82	16.7	16.7	16.7
Yeasts:			
Cryptococcus albidus, 496	0.33	0.33	1.67
Unclassified, 5Y	3.33	16.7	16.7
Unclassified, TY-2	0.33	0.33	1.67
Unclassified, Y-1000	16.7	16.7	16.7

(13), were superior to salts of sorbate, benzoate, and propionate as mold inhibitors in maple sirup. Therefore, the latter more commonly-used food preservatives were not included in subsequent experiments.

Propyl PHBA was found to be a more effective mold inhibitor than methyl PHBA (Table 2), substantiating the findings of Mathews *et al (13)* who reported that the necessary effective concentration of PHBA esters decreased with chain length of the alkyl ester.

The acid form of propyl and methyl PHBA (Tables 2 and 3) is effective at lower concentrations than the respective sodium salts of these esters. Nevertheless, in subsequent studies involving a variety of mold and yeast strains, the sodium salt of propyl PHBA was employed since its solubility in maple sirup was greater than the acid form.

The effectiveness of sodium propyl PHBA against several concentrations of the various mold and yeast strains is shown in Tables 3 and 4. In most cases, as the size of the inoculum was increased the inhibitory concentration required also was increased. None of the inocula, even at a level of 2000 cells per 100 ml, was able to grow in the presence of 16.7 mg (less than 0.02%) of sodium propyl PHBA. Since a contamination of 2000 cells per 100 ml of maple sirup is quite unlikely, it would appear that a concentration of 0.02% sodium propyl PHBA would be effective in controlling mold and yeast growth in maple sirup during ordinary handling (packaging, storage, and consumption). The lack of taste at this concentration would not interfere with the delicate maple flavor.

Acknowledgments

We wish to thank Mr. R. A. Bell for his technical assistance and Drs. T. C. Cordon and R. N. Costilow for supplying many of the cultures used in this study.

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Increasing Cooling Rates Through Thermal Radiation*

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(Manscript received April 1, 1960)

SUMMARY

From theoretical considerations it has been shown that a material enclosed in a dark non-reflective container will cool more rapidly than one enclosed in a reflective container.

Experimentally, under certain specified conditions, it has been demonstrated that the cooling time for material in black, non-reflective containers is 20 to 25% less than the cooling time for material in reflective containers.

Therefore, it may be concluded that a dark, non-reflective covering around a product should substantially decrease the cooling time in conventional air coolers.

IN THE COOLING and freezing of foods by conventional means, little advantage is taken of the effect of thermal radiation. It is theoretically possible to increase the heat transfer coefficient in air coolers from 20 to 80% by packaging the material to be frozen in a non-reflective dark wrap and using a freeezer with walls painted a non-reflective black. When a material is wrapped in a dark non-reflective color, it radiates heat to the freezer walls. The walls absorb this heat if they are also dark and non-reflective. The heat is in turn removed from the walls by the cold air in contact with them. The freezer walls also radiate heat if they are black, but this radiated heat is the same temperature as that of the cold wall.

If the freezer walls are of a highly polished reflective nature, they simply reflect the heat from the product, rather than re-radiate absorbed heat. When heat is reflected from the walls, it remains at the temperature of the incoming radiation rather than the temperature of the wall. Some of this reflected heat will be intercepted by the product and reabsorbed. If the room is very large and the product relatively small, only a small fraction of the reflected heat will be intercepted by the product. Thus, under such conditions, there is an advantage in employing a dark packaging material even though the freezer walls are highly polished.

Of course, in a situation in which the freezer is nearly filled with material, there would be little advantage in using reflective walls, even though the packaging material is dark, since nearly all the radiation reflected from the walls is intercepted by the material.

THEORETICAL CONSIDERATIONS

It is possible to demonstrate mathematically the effect of radiation by considering the rate of heat transfer through radiation. In the situation where one body is completely surrounded by a second body, e.g., the product (Body 1) enclosed in a freezer (Body 2), the rate of heat transfer through radiation is expressed according to Brown *(1)* by

$$q_{1,2} = A_1 \sigma (e_1 T_1^4 - a_{1,2} T_2^4) \qquad (1)$$

where:

$q_{1,2}$ = the net rate of heat transfer from Body 1 to Body 2 (Btu/hr)

A_1 = radiating surface area of Body 1

σ = Stefan-Boltzmann constant,

$$1730 \times 10^{-12} \frac{\text{Btu}}{(\text{hr})(\text{sq ft})(^\circ\text{R})}$$

e_1 = emissivity of Body 1 at temperature T_1

$a_{1,2}$ = absorptivity of Body 1 = emissivity of Body 1 evaluated at temperature T_2

T_1, T_2 = absolute temperature of Body 1 and Body 2 respectively, °R

In the case in which Body 1 is a non-reflective black, both the absorptivity and emissivity are unity. If Body 1 were a gray body, their absorptivity and emissivity would be equal to each other but not equal to unity.

If one considers a small reflective metal container which is being cooled by natural convection in a relatively large freezing room, the rate of heat transfer in Btu/hr at any time from the container may be expressed by:

$$q = h_c A_1 (T_1 - T_a) \qquad (2)$$

where:

q = rate of heat transfer from the container (Btu/hr)

A_1 = area of the container (sq ft)

T_a, T_1 = temperature of the surrounding air and temperature of container, respectively, at any time (°F)

h_c = heat transfer coefficient for air

$$\left(\frac{\text{Btu}}{(\text{hr})(\text{sq ft})(^\circ\text{F})}\right)$$

An expression commonly used for calculating the heat transfer coefficient for air in natural convection surrounding cylinders according to Brown *(2)* is

$$h_c = 0.27 \frac{(Ta - T_1)^{.25}}{D} \frac{\text{Btu}}{(\text{hr})(\text{sq ft})(^\circ\text{F})} \qquad (3)$$

where:

D = diameter of the container (ft)

If a container with an initial temperature of 70° F has a diameter, "D," of 0.224 ft and the temperature of the freezing room is 0° F, then initially

* Contribution Number 396 from the Department of Food Technology, Massachusetts Institute of Technology, Cambridge, Massachusetts.

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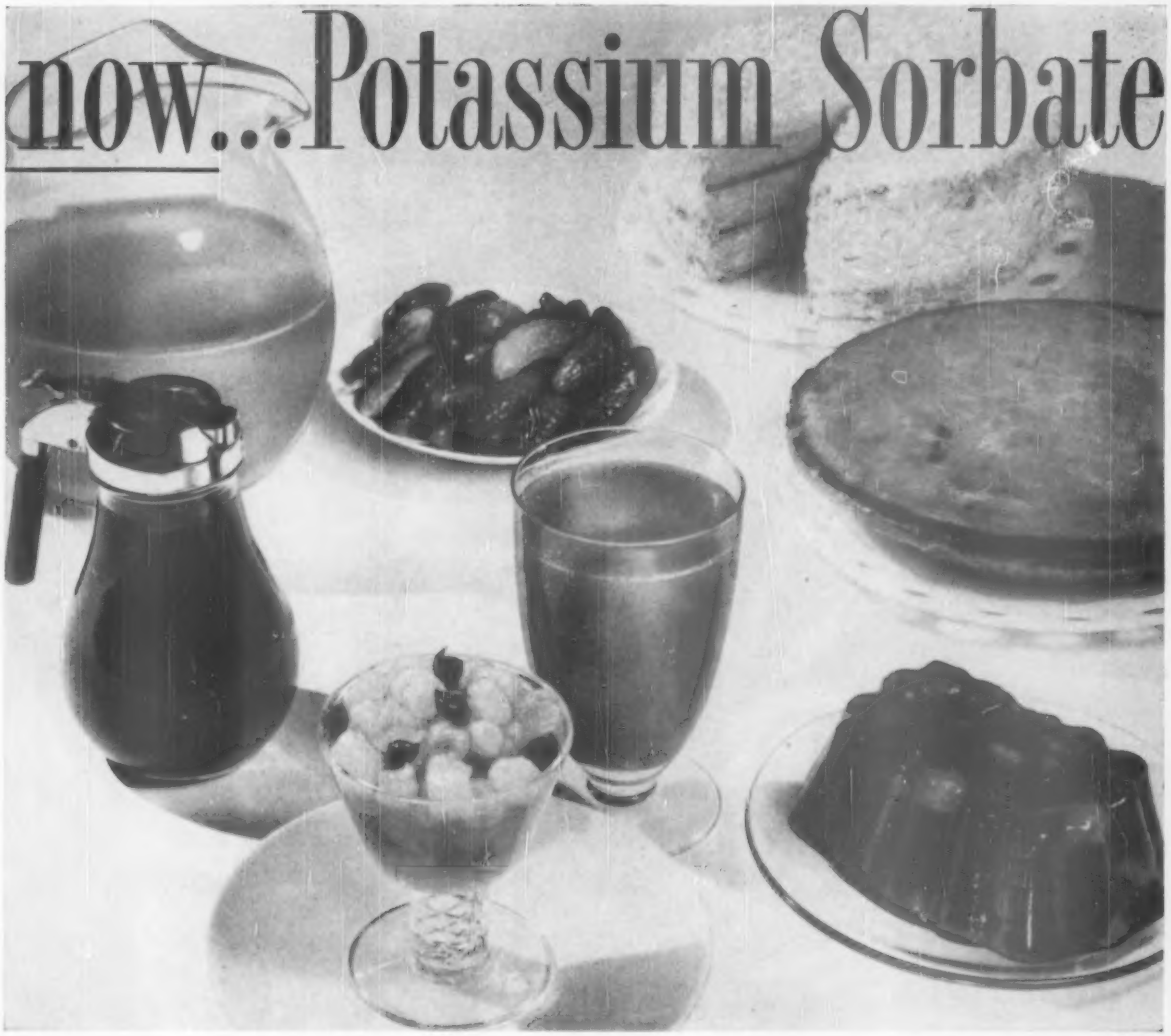

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$$h_c = 1.14 \frac{\text{Btu}}{(\text{hr})(\text{sq ft})(^\circ\text{F})}.$$

When the surface temperature of the container has dropped to 32° F, then $h_c = 0.92 \frac{\text{Btu}}{(\text{hr})(\text{sq ft})(^\circ\text{F})}$.

Thus, between surface temperatures of 70° F and 32° F the average h_c value is $1.03 \frac{\text{Btu}}{(\text{hr})(\text{sq ft})(^\circ\text{F})}$.

Since the average temperaure between 70° F and 32° F is 51° F, the average rate of heat transfer per unit area due to convection is:

$$\frac{q}{A} = 1.03\ (51 - 0) \cong 51 \frac{\text{Btu}}{(\text{hr})(\text{sq ft})}$$

If the container were painted black, heat transfer due to radiation (in addition to the heat transfer through convection) occurs.

The heat transfer coefficient due to radiation, h_r, may be determined by equating equations (1) and (2) for black bodies (see reference 1). This results in,

$$h_r = \sigma \left[\frac{T_2^4 - T_1^4}{T_2 - T_1} \right] \qquad (4)$$

where:

h_r = heat transfer coefficient due to radiation $\frac{\text{Btu}}{(\text{hr})(\text{sq ft})(^\circ\text{F})}$

T_1, T_2 = absolute temperature of container surface and freezer walls, respectively (°R)

Equation (4) assumes Body 1 and Body 2 are both black. (If the freezing room is very large compared to the container, it behaves as if the walls were black.)

When the container surface is at 70° F,

$$h_r = 0.876 \frac{\text{Btu}}{(\text{hr})(\text{sq ft})(^\circ\text{F})}.$$

When the surface is at 32° F,

$$h_r = 0.765 \frac{\text{Btu}}{(\text{hr})(\text{sq ft})(^\circ\text{F})}.$$

The average h_r for these two surface temperatures is $0.82 \frac{\text{Btu}}{(\text{hr})(\text{sq ft})(^\circ\text{F})}$.

If one considers both convection and radiation, the average rate of heat transfer for a black surface between surface temperatures of 70° F and 32° F and an ambient temperature of 0° F, is:

$$\frac{q}{A} = (0.82 + 1.03)\ (51 - 0) = 94 \frac{\text{Btu}}{(\text{hr})(\text{sq ft})}.$$

Compared with the $51 \frac{\text{Btu}}{(\text{hr})(\text{sq ft})}$ which results from convection cooling alone, the $94 \frac{\text{Btu}}{(\text{hr})(\text{sq ft})}$ indicates an increase of 85% in the average heat transfer rate from the black surface as compared to the reflective surface.

It should be kept in mind that this average increase in cooling rate has been determined for the surface of the container. The effect on the interior portions of the container would not be as great since conduction of heat from the interior to the surface would reduce the heat transfer rate.

EXPERIMENTAL STUDIES

The effect of heat transfer through radiation during cooling was determined experimentally by comparing the length of time required to cool the centers of black containers and reflective containers under similar conditions.

The reflective containers used were standard No 1 Picnic Cans, and the black containers used were No 1 Picnic Cans painted with a flat black paint. The cooling rates for water and concentrated orange juice were determined in these standard reflective and black-painted containers under various conditions.

The experimental cooling chambers used were the freezing compartment of a household refrigerator and a commercial freezing room. Natural convection prevailed in the freezing compartment of the refrigerator, while the commercial freezing room contained a fan. In neither case were the walls of the coolers painted black. The experimental data in Table 1 show that in all instances the time required to cool the center of the black container was 20 to 25% less than the time required to cool the center of the reflective container.

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TABLE 1

Comparison of cooling times in reflective and black containers

Can condition	Material	Type of cooler	Freezer temp °F	Initial temp °F	Final temp °F	Time to cool center to final temp (min)
Black	Water	Household refrigerator freezer	18°	66°	34°	90
Reflective	Water	Household refrigerator freezer	18°	66°	34°	110
Black	Water	Commercial	0°	81°	41°	20
Reflective	Water	Commercial	0°	81°	41°	25
Black	Water	Commercial	−20°	72°	48°	15
Reflective	Water	Commercial	−20°	72°	48°	20
Black	Conc orange juice	Commercial	−40°	64°	38°	35
Reflective	Conc orange juice	Commercial	−40°	64°	38°	40

A Method for Mathematically Evaluating the Significance of Small Changes in the Phosphatase Activity of Milk[a]

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SUMMARY

This paper introduces a different method of interpreting the phosphatase test. Milk samples were tested for phosphatase content using the method of Sanders and Sager. The color intensity readings obtained from these tests were interpreted in two ways: the conventional standard phenol curve, and a statistical procedure called a "biological assay" technique. The latter technique had more precision than the conventional one and could be quite useful as a research tool.

REACTIVATION of the phosphatase enzyme in pasteurized milk *(2, 4, 8, 9)* has raised some questions about the interpretation of phosphatase test data. This reactivation, or increased phosphatase activity, most often occurred when the milk had been heated to temperatures higher than those used for commercial pasteurization.

Occasionally milk plants in Oklahoma have reported phosphatase positive samples from milk that had originally been pasteurized at 161° F (71.67° C) and was phosphatase negative immediately after pasteurization *(7)*. The objective of this study was to measure the changes in phosphatase activity which occurred during incubation when milk had been heated at temperatures similar to those used in commercial pasteurization.

Preliminary studies *(6)* indicated that only small changes in phosphatase activity occurred when milk was heated at 62.5° C (144.5° F) or 66.9° C (152.4°F). Thus, a statistical method of evaluating the data was necessary to detect these changes. A "biological assay" technique, termed a "validity check" procedure *(3)*, was found suitable. The purpose of this paper is to demonstrate the usefulness of this statistical method as a research tool when applied to phosphataste data and to compare the results obtained with those collected by the customary method of interpreting phosphatase data.

EXPERIMENTAL METHODS AND RESULTS

Duplicate samples of mixed herd milk were heated to either 62.5° C (144.5° F) or 66.9° C (152.4° F). One duplicate was tested for phosphatase activity immediately after heating and the other was tested after 24 hr incubation at 32.2° C (90° F).

Fourteen ml aliquots of milk were pipetted into 16 x 150 mm glass test tubes. The tubes were then sealed in flame. The samples were heated in an oil bath, which had been previously adjusted either to 62.5° C or 76.7° C ± 0.1° C. Ten min were required to raise the temperature of the milk in the 62.5° C bath from 40° C to 62.5° C. It was held at 62.5° C for 12.5 min and then cooled to 40° C in 30 sec. Two min were required to heat the milk in the 76.7° C bath from 40° C to 66.9° C. No holding time was involved in this heat treatment, and the milk was then cooled to 40° C in 30 sec.

After heating under either of these sets of conditions the milk had a phosphatase activity of 2.5 to 5.4 γ phenol/ml of milk. Since 4 γ phenol/ml is the maximum acceptable pasteurization value for milk *(1)*, the samples were considered to be sufficiently heated.

The Sanders and Sager phosphatase test *(1)* was used for all the samples in this work and the intensities of the colors obtained from these tests were measured with a Fisher Neflurometer at 610 mmc.

Color intensities were converted into phenol units by two different methods. The first involved the use of a single standard curve calculated from data obtained by testing phenol solutions of known concentration. The second was a statistical procedure called a "biological assay" technique.

The standard curve technique is outlined in *Standard Methods for the Examination of Dairy Products (1)*. This standard curve was obtained by fitting a straight line to the data obtained by testing phenol solutions of known concentration. The equation of the line for this work was:

$$Y = 3.72X + 0.70$$

where

Y = color intensity as absorbance, and
X = γ phenol/ml.

The phosphatase activity of each milk sample was determined by substituting the color intensity obtained for Y in the above equation and solving for phosphatase activity (X). The data obtained by using this equation are shown in Table 1. Using this method, 9 of the 14 samples increased in phosphatase activity after 24 hr incubation. The average increase was 0.49 γ but this increase was not statistically significant at the 5% level of probability.

The statistical calculations used in the second method were patterned after the "biological assay" technique described by Finney *(3)*. In order to apply this method, it was necessary to

TABLE 1

Phosphatase activity of milk heated to 62.5° C or 66.9° C before and after 24 hour incubation

(Evaluated with a standard phenol curve)

Heating temperature	Sample number	Hours incubation		Change after 24 hours
		0	24	
°C		γ phenol/ml	γ phenol/ml	γ phenol/ml
62.5	1	4.2	4.5	0.3
	2	5.2	5.0	−0.2
	3	3.3	4.3	0.9
	4	5.4	7.1	1.7
	5	4.6	4.5	−0.1
	6	2.9	2.7	−0.2
66.9	11	4.4	5.5	1.1
	12	3.1	3.9	0.8
	13	5.3	4.0	−1.3
	14	2.8	3.5	0.7
	15	2.5	3.5	1.0
	16	3.3	5.5	2.2
	17	2.7	3.0	0.3
	18	2.8	2.5	−0.3

[a] Published with the approval of the Director of the Oklahoma Agricultural Experiment Station as Journal Article No. 456.

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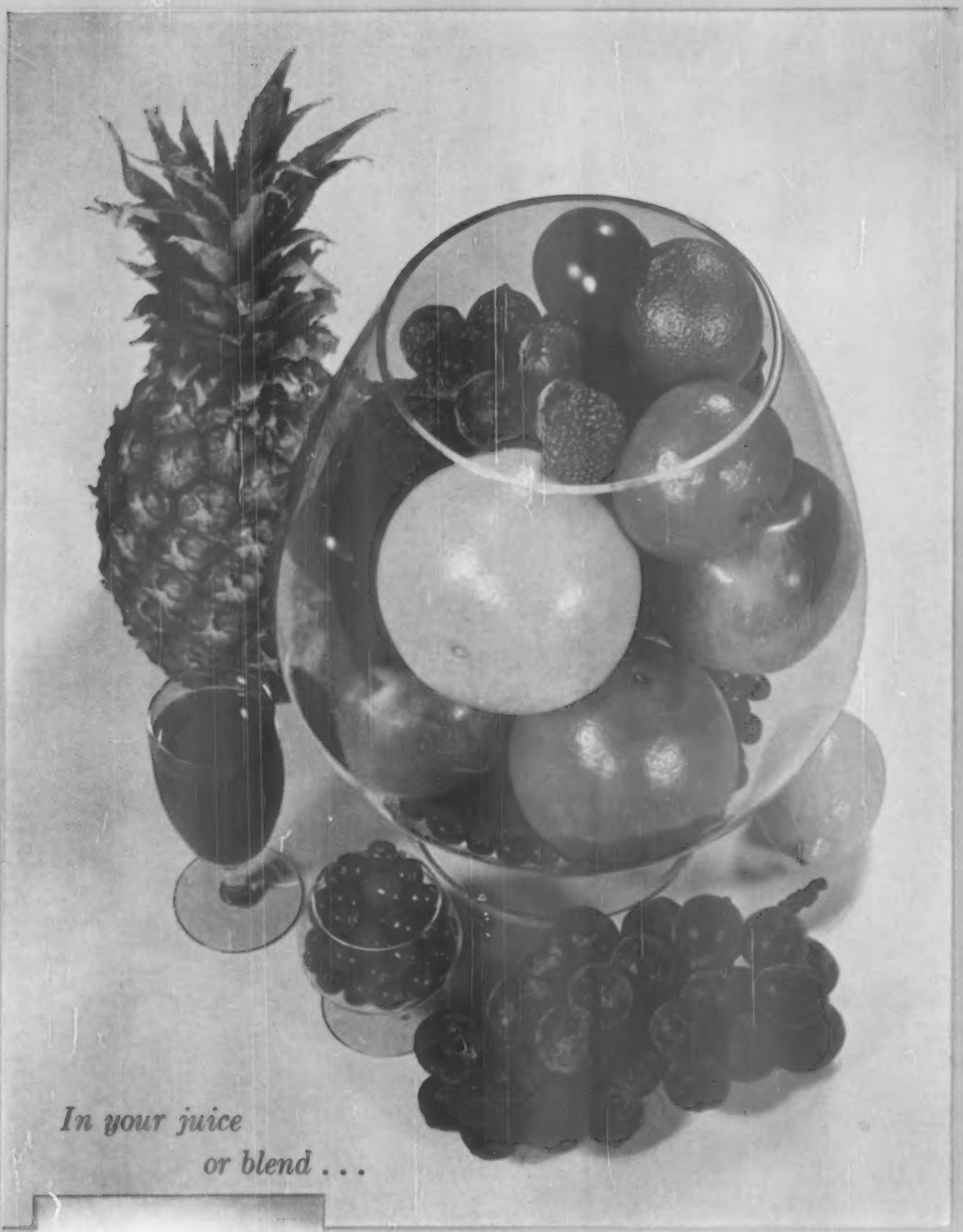

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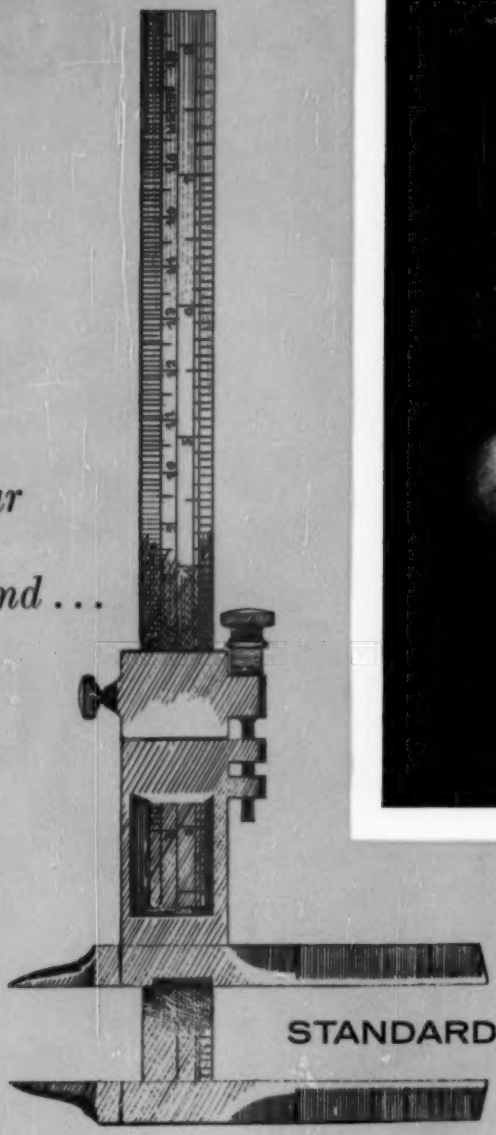

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measure the color intensities produced by duplicate aliquots of 0.0, 0.5, 1.0 and 2.0 ml, which were measured from each tube of heated milk. These aliquots were diluted to a final volume of 2 ml with distilled water and then tested for phosphatase activity using the Sanders and Sager method. A fresh phenol standard (10 γ phenol/ml) was tested in the same manner along with each milk sample.

To evaluate the data obtained, regression lines, representing color intensity vs concentration in ml, were calculated for each sample and its standard. The phosphatase activity of the milk sample was obtained by dividing the slope of the line representing the milk by the slope of the line representing the standard. These calculations involved the solution of 6 simultaneous equations and could be done on a desk calculator. Since many samples were analyzed in this work, an IBM 650 Speed Computer was used. Programs exist for this machine which could solve these equations in a few minutes *(5)*.

The results obtained when using the "biological assay" technique are shown in Table 2. With this method 10 of the 14 samples showed an increase in phosphatase activity after the 24 hr incubation period. The average increase was 0.89 γ and this increase was statistically significant at the 2.5% level of probability.

DISCUSSION

The main advantage of the statistical "biological assay" technique was an increase in precision as compared to the standard curve procedure. The small increase in phosphatase activity after 24 hr incubation was questionable when measured by the conventional method, but it became statistically significant when measured by the "biological assay" technique.

TABLE 2

Phosphatase activity of milk heated to 62.5° C or 66.9° C before and after 24 hour incubation (Evaluated by biological assay technique)

Heating temperature	Sample number	Hours incubation		Change after 24 hours
		0	24	
°C		γ phenol/ml	γ phenol/ml	γ phenol/ml
62.5	1	4.9	5.5	0.6
	2	4.4	5.1	0.7
	3	3.1	4.3	1.2
	4	4.7	7.1	2.4
	5	5.6	4.8	−0.8
	6	3.5	3.4	−0.1
66.9	11	4.5	6.7	2.2
	12	3.3	4.3	1.0
	13	4.9	3.9	−1.0
	14	2.1	3.7	1.6
	15	2.3	3.5	1.2
	16	3.4	5.4	2.0
	17	2.3	3.0	0.7
	18	2.8	2.7	−0.1

The precision of the standard curve technique was limited by the experimental errors inherent in determining the curve and in testing the milk sample. These errors have frequently been ignored since they were difficult to calculate. However, the experimental errors are easier to calculate when using the "biological assay" technique. Thus it was possible to estimate how much of the change in phosphatase activity was due to variations in the milk and how much was caused by experimental error.

The new technique also provided a quantitative method for checking the validity of each determination on each milk sample and its standard. This evaluation did not depend on the judgment of the researcher but was a part of the mathematical calculations involved in the technique. Thus, with this technique it would be possible to compare the data of different technicians from the same or different laboratories. Such comparisons were difficult, and often impossible, when the conventional method of interpreting phosphatase data was employed.

Acknowledgment

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Relationship Between Pork Leanness and Moisture Content

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(Manuscript received May 16, 1960)

SUMMARY

The moisture contents of lean and adipose tissues of pork were studied. The relationship between moisture content and leanness of pork was established and expressed by the equation

$$L = 1.5\ M - 11.5$$

where L is the percent of lean and M is the percent of moisture.

This equation may be applied for quantitative determination of lean in the meat industry.

QUANTITATIVE ESTIMATION of the relative proportions of lean and fat in meat is of great importance to the meat industry. The present paper deals with the quantitative determination of lean in pork.

The concept of protoplasm suggests a substantially fixed composition of water and proteins in the fat-free animal tissues. This idea is supported by studies on animals *(5, 7, 10, 11, 12)* and even on human subjects *(3)*. Accordingly, total water content of the animal tissues would allow one to estimate the lean content of these tissues. Evidence for the validity of such an assumption comes from direct chemical analysis of animal tissues.

Murray *(11)* established the constancy in the composition of the lean body mass. He found that lean pork, depending on the age and food of the animals, contains from 74.4% to 78.5% moisture. Behnke *(3)* reached the conclusion that fat-free body tissue is of constant composition containing approximately 80% water. Pace and Rathbun *(12)* working with guinea pigs found that the water content of various tissues of the fat-free body is nearly constant; fresh muscle tissue contained 74.65 ± 0.66% and adipose tissue 10.25 ± 5.97% water. Callow *(4)* in a review article indicated 77.0 ± 0.5% as a highly probable water content of the fat-free fraction of pork, lamb, beef, and veal.

There seems to be considerable confusion as to the meaning of the word "lean meat." Nutritionally, lean meat is recognized as an excellent source of high-quality proteins *(1, 8)*. Consumers, meat packers, and sausage makers call lean that part of meat where no visible fatty tissue may be observed. This definition seems to be sound from the standpoint of trade and nutrition and is adopted as the basis for lean determination in this work. However, lean contains intramuscular fat; 2.36% as indicated by Pace and Rathbun *(12)*, or from 1% to 2% according to Keys and Brozek *(6)*. Therefore, the moisture values of the fat-free meat given in the previous paragraph are somewhat higher than those of fresh meat. On the other hand, the fatty tissue contains proteins of connective tissue type *(14)* which are, of course, associated with water. This proteinaceous fraction is not included in "lean meat" as defined above because connective tissue type proteins are of rather poor nutritive value *(1)*.

To devise fast and adequate methods for determining the composition of meat has long been desirable. Anderson *(2)* suggested using potassium-40 counts as a non-destructive method of determining the amount of lean meat present in live animals, carcasses, and cuts of meat. Saffle and Bratzler *(13)* have derived a formula to use specific gravity to determine leanness. In some laboratories leanness is calculated from the formula: % lean = 100 − % fat − an estimated value from 2 to 7 (depending on the amount of the adipose tissue) *(9)*. The so-called "knife test" involves cutting out the lean tissue from the adipose, and reporting the percent by weight of the separated lean.

Pace and Rathbun *(12)* demonstrated a linear relationship between the water content and fat-free body weight. Consequently, the calculation of the lean content from the moisture content of meat should be possible. Such a calculation involves the assumption that the average moisture contents for the 100% lean tissue and 0% lean tissue (pure adipose tissue) are fixed. The literature reviewed above seems to justify such an assumption.

The object of this work was to determine the average moisture contents of 100% and 0% lean pork and to correlate pork moisture content to lean content.

EXPERIMENTAL PROCEDURE

The general experimental procedure consisted of moisture determinations on samples taken from various locations on pork carcasses. Samples were taken by the cork-borer plug technique. In each sample plug, slivers of pure red muscle tissue were separated from pure white adipose tissue. The muscle tissue was considered 100% lean, whereas the adipose tissue was considered 0% lean. Slivers, separated from the sample plugs, weighed approximately 2 g. Moisture was determined by drying to constant weight in the air oven at 105° C. Determinations were performed on pure red muscle samples from the ham, loin, shoulder, side, and neck of a carcass. Adipose tissue for the determinations came from mesenteric depots, back, shoulder, and sides.

In all, 150 determinations were performed. When the water contents of pure lean and pure adipose tissues were determined, mixtures of the two tissues were prepared. Mixtures contained 80%, 60%, 40%, and 20% lean. Moisture and analytical fat were determined on these samples by a special method *(15)*.

RESULTS AND DISCUSSION

In Table 1, it is shown that the moisture content of pure lean muscle tissue was relatively constant. The standard deviation was 1.50%, or approximately 2% of the total moisture content. It must be emphasized that the moisture in lean was not determined on a fat-free basis, i.e., the intramuscular fat was included in

TABLE 1

Moisture content of pork muscle and adipose tissues (in percent)

Tissue	Mid-range	Mean	Standard deviation
Muscle	75.05	75.19	±1.50
Adipose	8.35	7.82	±1.73

the calculations. The standard deviation of 1.73% in the moisture content of the pure adipose tissue was large, approximately 20% of the total moisture content. The mid-ranges and mean values were close to each other implying a normal distribution of data.

When moisture content was plotted as the abscissa, per cent leanness as the ordinate, and a line was drawn between the average moisture contents of 0% and 100% lean, the slope of the line was 1.48. Variation in the average moisture contents of 0% and 100% lean made the slope vary within the limits of 1.48 ± 0.03.

When the mean moisture contents were considered, the equation of the line between the two points was $y = 1.48\,x - 11.5$. When the mid-range moisture contents were considered, the equation of the line between the two points was $y = 1.50\,x - 12.5$. Figure 1 shows

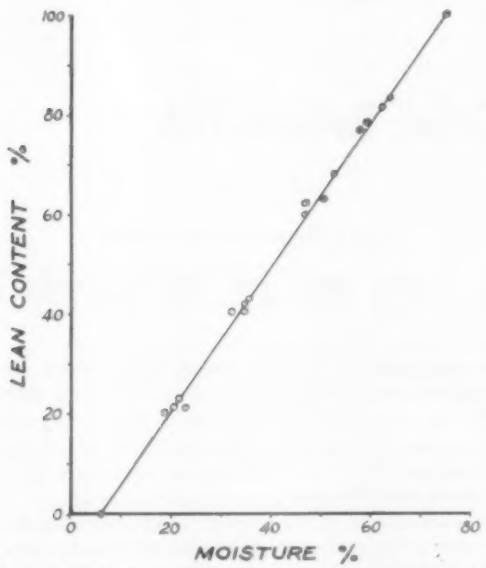

Figure 1. Relationship between pork leanness and moisture content.

the line drawn between 0% and 100% lean average moisture coordinates; then the points, obtained in the moisture determinations of the premixed samples, were plotted. In plotting, the known lean composition of the premixed samples was used as the lean coordinate. It may be easily observed that a linear relationship between leanness and moisture content existed throughout the range of composition. The equation representing this curve is

$$L = 1.48\,M - 11.5 \qquad (1)$$

where L is leanness in percent and M is moisture in percent.

Table 2 presents the results of the above experiments. Column 2 of the table reports the composition of the mixed samples. Column 3 shows lean derived from the use of Equation (1). Column 4 shows the actual error and column 5 the error expressed as percentage of column 2. It is important to note that the error increased for lower values of lean. At 20% lean, it had increased beyond tolerable limits. This was undoubtedly due to the wide variation in the moisture content of adipose tissue. Moisture content

TABLE 2

Comparison of actual lean with lean derived from the lean equation on premixed samples (in percent)

1 Sample	2 Actual lean	3 Lean from equation	4 Error	5 Per cent error
1	83.3	83.9	0.6	0.7
2	81.3	81.5	0.2	0.3
3	67.9	67.2	0.7	1.1
4	63.2	64.6	1.4	2.3
5	60.1	58.5	1.6	2.7
6	43.3	41.8	1.5	3.6
7	42.0	40.5	1.5	3.7
8	23.3	20.6	2.7	11.6
9	21.4	18.9	2.5	11.8
10	20.3	16.3	4.0	19.5

of the low lean samples originated to a large extent in the adipose tissue. Generally, the moisture content of the adipose tissue is quite variable, thus the percent error was larger for these samples.

Table 3 shows the comparison of lean values derived from the use of Equation (1) with lean values obtained by subtracting from 100 the fat percent of the samples. It is interesting that for the lower lean values, "100 minus fat percent" values were considerably higher than those derived from the Equation (1). This is so because the proteinaceous part of the adipose tissue was included as lean in the former calculation and, therefore, interfered with the definition of lean adopted in this paper. On the other hand, intracellular fat of 100% lean meat intervened to lower the lean content derived from "100 minus fat per cent."

CONCLUSIONS

A correlation of the moisture content with leanness of pork has been established. The correlation is good for leaner cuts of pork but percent error increases as leanness decreases. Equation (1) is well applicable to lean contents higher than 40 per cent and, therefore, can be used quite successfully for quality control purposes in the meat industry, since commercial cuts of meat rarely contain less than 40% lean.

TABLE 3

Comparison of lean values derived from the lean equation with those obtained from "100 minus fat percent" (in percent)

Name of cut	Lean from equation	Lean from "100 − % fat"
100% lean trimmings	100.9	98.8
95% lean trimmings	96.8	93.7
Loin trimmings	89.3	86.3
Shoulder trimmings	68.9	68.7
50% lean trimmings	51.2	53.8
Belly trimmings	41.6	45.3

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Formation of Acetoin in Cod and Other Bottom-Fish Fillets During Refrigerated Storage[a]

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SUMMARY

Acetoin and the total volatile bases were measured in samples of commercial bottom-fish fillets that were stored at 34° F. The content of acetoin increased from <1 to 7–10 mg/100 g after 4 to 8 days storage. The usefulness of the acetoin content as a measure of quality of commercial fillets appears to be quite limited, because the increase of acetoin does not occur until just before the time the sample would be considered unacceptable.

THE ACIDIC AND NITROGENOUS bacterial degradation products of fish flesh have been studied extensively, but the neutral products have received little attention. The carbonyls appear to be of special importance in this group since they have been associated with undesirable flavor and odor changes in foods.

The carbonyl determination has been tested by Farber *(1)* as a quality test for fishery products. Ota *(5)* fractionated the volatile carbonyls from fish stored at ambient temperatures. He found acetaldehyde, butyraldehyde, and acetoin in the spoiled flesh of sardine, mackerel, and a flatfish, whereas he found only acetaldehyde in fresh tissue. Mangan *et al (4)* reported finding acetaldehyde in the extracts of haddock that had been iced 8 days.

The objectives of the present work are to determine the main carbonyl compounds formed in bottom-fish fillets stored at 34° F and to determine the relationship of carbonyl content to volatile nitrogen content and to sensory acceptability.

EXPERIMENTAL

Materials and storage. Freshly cut, unwashed bottom-fish fillets, obtained commercially, were used for the major part of this study. The species used were cod *(Gadus macrocephalus)*, English sole *(Pseudopleuronectes dignabilis)*, rockfish *(Sebastodes* sp.*)*, and lingcod *(Ophiodon elongatus)*. In part of this study cod were used which had been caught and iced 4 hr earlier. Fillets were cut from these fish in the laboratory and used unwashed.

The fillets were cut into pieces of 40–50 g each, and the pieces from one lot (about 15 lb) were mixed together. Portions of approximately 300 g were placed in sterilized sample jars, fitted with lids having a cotton-plugged air vent. Samples were

[a] Contribution No 590 from the technological laboratories of the Bureau of Commercial Fisheries, Fish and Wildlife Service, U. S. Department of the Interior.

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held in a fan-equipped refrigerator at 34 ± 2° F for periods up to 15 days, after which they were frozen at −20° F and held until analyzed.

Analysis of carbonyls. The techniques of steam distillation and benzene extraction were used to remove carbonyls from flesh. In the steam distillation method, fish flesh (30 g) was homogenized in a blender with 100 ml of water. The homogenate was steam distilled rapidly into a receiver containing a saturated solution of 2,4-dinitrophenylhydrazine in 2 N HCl. After allowing the solution to stand for 2 hr at room temperature, the hydrazones were extracted from it with about 5 portions (40 ml each) of carbonyl-free ether. The ether solution was washed with 10 ml of 10% Na_2CO_3, dilute HCl, and water. The solution was dried over anhydrous Na_2SO_4 and the ether was evaporated to near dryness before the residue was taken up in benzene.

In the benzene extraction, fish flesh (30 g) was ground in a mortar with an equal weight of anhydrous Na_2SO_4 and extracted with about 5 portions (10 ml each) of carbonyl-free benzene. The extract was reacted with trichloroacetic acid and 2,4-dinitrophenylhydrazine by heating for ½ hr at 60° C. The reaction mixture was washed with a small volume of 10% Na_2CO_3 soln and 2% HCl, dried over anhydrous Na_2SO_4, and concentrated.

The benzene solutions were chromatographed on Whatman 3MM paper using a descending technique. The n-heptane rich layer of a 1:1 methanol/heptane mixture was used as developing solvent. (The system was equilibrated 12 hr with the methanol-rich layer before development.)

Acetoin was estimated colorimetrically by reacting an aliquot (2 to 5 ml) of the benzene extract of flesh in a 25-ml flask with 1.5 ml 4.3% trichloroacetic acid in benzene and 2.5 ml of 0.05% 2,4-dinitrophenylhydrazine in benzene for ½ hr at 60° C. The flask was cooled, treated with 5 ml of 4% KOH in absolute ethanol and made to volume with absolute ethanol. After 15 min development period, the absorbance (A) was measured at 490 and 435 mμ, using a blank prepared with the reagents. The content of carbonyl was calculated using the absorbance obtained by subtracting $A_{435\ m\mu} - A_{490\ m\mu}$ and interpolating from a standard curve prepared with acetoin.

Acetaldehyde was estimated spectrophotometrically at 353 mμ after eluting acetaldehyde 2,4-dinitrophenylhydrazone from the chromatogram with 95% ethanol.

Total volatile nitrogen. Volatile nitrogen was determined by the method of Stansby *et al (9)*.

Sensory evaluation. Appearance and odor of raw fillets and the odor of cooked fillets were used to determine when fillets were no longer acceptable.

RESULTS AND DISCUSSION

Identification of carbonyls. A typical paper chromatogram of the 2,4-dinitrophenylhydrazones prepared from the steam distillates of cod flesh is shown in Figure 1. In the distillates of fresh tissue there were two components whose migration rates corresponded to the hydrazones of formaldehyde and acetaldehyde. The absorption maximum of the eluates of these spots were in agreement with the absorption maximum of the hydrazones of formaldehyde and acetaldehyde. Owing to this agreement of absorption maxima and chromatographic behavior, it was concluded that these components were most probably formaldehyde and acetaldehyde.

In the 2,4-dinitrophenylhydrazone mixture from the steam distillate of flesh stored 4 to 8 days, there was formaldehyde, acetaldehyde, and a component that had a migration rate similar to that of acetoin (Figure 1). The melting point of the crystals obtained from the eluate of this component was 107–109° C (uncor). The melting point of the mono 2,4-dinitrophenylhydrazone derivative of acetoin was

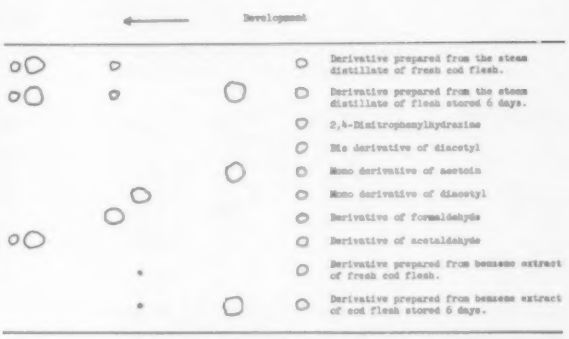
Development
Derivative prepared from the steam distillate of fresh cod flesh.
Derivative prepared from the steam distillate of flesh stored 6 days.
2,4-Dinitrophenylhydrazine
Bis derivative of diacetyl
Mono derivative of acetoin
Mono derivative of diacetyl
Derivative of formaldehyde
Derivative of acetaldehyde
Derivative prepared from benzene extract of fresh cod flesh.
Derivative prepared from benzene extract of cod flesh stored 6 days.

Figure 1. Chromatogram of 2,4-dinitrophenylhydrazones of known compounds and those prepared from the benzene extracts and the steam distillates of cod flesh.

106–108° C (uncor). Since the bis 2,4-dinitrophenylhydrazone derivatives of acetoin and diacetyl are identical and since the bis derivative did not migrate with the solvent system used (Figure 1), an independent test had to be used to eliminate the possibility of the presence of diacetyl. The Prill and Hammer test *(7)* was negative indicating that diacetyl was not present in detectable amounts.

Acetaldehyde and formaldehyde were not detected in the chromatograms of the benzene extracts of flesh. The absence of these compounds might be attributed to the simple extraction method used. Tests showed that the recovery of acetaldehyde from fish flesh by this method was poor. Hughes *(2)* has suggested that formaldehyde may react with amino groups under conditions similar to that used here. He cited a reference in which it was found that small quantities of formaldehyde added to minced herring flesh, in the cold, could not be detected immediately afterwards.

The trace of formaldehyde found in the chromatograms of the steam distillate of flesh was not considered in the quantitative work. The finding of a trace of formaldehyde does not agree with the results of Ota *(6)* who was unable to detect formaldehyde in the steam distillate of fish flesh until after heating the flesh for 1 hr at 113° C.

Estimation of acetaldehyde. The results from a limited number of samples showed that there was no measurable change in the acetaldehyde content of fish flesh after 8 to 10 days' storage.

Estimation of acetoin. The content of acetoin and volatile bases and the sensory evaluation of fresh and stored cod fillets are shown in Table 1. The sensory

TABLE 1

Content of acetoin and of volatile base, and the sensory evaluation of cod fillets stored at 34° F

Time	Series 1		Series 2	
	Acetoin	Volatile bases	Acetoin	Volatile bases
Days	*Mg/100 g*	*Mg N/100 g*	*Mg/100 g*	*Mg N/100 g*
0	<1	9.0	<1	9.1
2	<1	14.0	<1	9.8
4	10	29.4	<1	11.0
6	....	....	7	34.3
7	4	59.8	....	....
8	....	....	7	44.7

TABLE 2

Content of acetoin and of volatile base and the sensory evaluation of lingcod, rockfish, and sole fillets held at 34° F

Time	Lingcod			Rockfish			Sole		
	Acetoin	Volatile bases	Sensory	Acetoin	Volatile bases	Sensory	Acetoin	Volatile bases	Sensory
Days	*Mg/100 g*	*Mg N/100 g*		*Mg/100 g*	*Mg N/100 g*		*Mg/100 g*	*Mg N/100 g*	
0	<1	8.4	Acceptable	<1	8.5	Acceptable	<1	10.3	Acceptable
2	<1	9.1	Acceptable	<1	11.5	Acceptable	<1	9.5	Acceptable
4	<1	10.2	Acceptable	6	31.8	Acceptable	1	12.1	Acceptable
6	6	23.1	Acceptable	6	57.7	Not acceptable	8	31.3	Acceptable
8	6	27.6	Not acceptable	6	66.5	Not acceptable	6	42.9	Not acceptable

evaluation indicated that the rise in acetoin content began not long before or at about the same time that the fillets would be considered unacceptable. The volatile nitrogen increase followed a pattern similar to that of acetoin up to the point of unacceptability. Series 1 and 2 were handled in the same manner. The differences in storage life were attributed to differences in the quality of the starting material.

The study on cod was extended to include the commercial fillets of English sole, rockfish, and lingcod. These results are reported in Table 2 and in general are similar to those found for cod.

When the fillets of very fresh cod (prepared 4 hr after capture) were stored at 34° F, it was found that the acetoin content reached detectable levels somewhat later than the commercial fillets. In these samples the maximum value for acetoin was obtained after 9 days' storage at 34° F, whereas the maximum for commercial fillets was obtained after 4 to 6 days. These fillets were not judged unacceptable until 13 to 15 days' storage. This indicated that the relationship of acetoin content of stored fillets and the sensory score is affected by the quality of the fish from which the fillets are cut.

The usefulness of the acetoin content as a measure of the quality of commercial fillets appears to be quite limited, because the sharp rise in acetoin content does not occur until just before the time when they would be considered unacceptable.

Origin of acetoin. The formation of acetoin in stored fish fillets at about the same time as the formation of volatile base suggests that bacteria are responsible. It was shown that some isolates from commercial cod fillets produced acetoin or diacetyl or both when cultured on a media containing glucose. Sigurdsson and Wood *(8)* showed that bacterial isolates from decomposing cod muscle gave a positive test for acetoin. Liston *(3)* has been unable to demonstrate the presence of acetoin-producing organisms in the flora of live fish.

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Experimental Preservation of Fresh Beef with Antibiotics and Radiation

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SUMMARY

The application of 7 ppm of chlortetracycline to the surface of beef followed by irradiation with 0.1 megarad resulted in more effective inhibition of microbial growth during storage at 34° F for 30 days than the independent use of antibiotic and radiation. The useful limits of chlortetracycline concentration are 0.5 to 10 ppm and the most suitable radiation dose is 200 kilorads. Tetracycline and oxytetracycline were also effective, the former manifesting maximum inhibition. Storage of meat at 34° F was considerably superior to 40° F irrespective of the treatment. Microbial counts were lower in treated meat packaged in Saran film than in Cellophane and polyethylene.

THE APPLICATIONS of antibiotics to the improvement of food processing and preservation have been experimentally evaluated from many aspects *(5, 13)*. These efforts have resulted in the commercial use of certain broad-spectrum antibiotics such as chlortetracycline and oxytetracycline in the preservation of fresh poultry and fish in the United States as well as fresh meats in other countries *(9)*. One of the most important limiting factors in the storage life of fresh beef is bacterial spoilage due to the *Pseudomonas* and *Achromobacter* genera *(8)* and chlortetracycline is one of the most effective antibiotics for reducing such spoilage *(5)*.

Although ionizing radiations also have been intensively investigated for their potentialities in food preservation *(2, 7, 11)* radiation processing of foods is not yet a commercial reality. One of the problems involves radiation side effects; for instance, certain foods such as fresh beef acquire undesirable odors and flavors when exposed to radiation sterilizing doses of 2 to 4 megarads *(1, 4, 6, 12)*. However, such side reactions are negligible in beef irradiated at levels up to 0.3 megarad which constitute a radiation "pasteurization" extending the storage life of refrigerated beef *(3, 10)*.

The incorporation of both antibiotic and pasteurizing doses of radiation into a preservation process for fresh foods should yield a broader spectrum of microbial inhibition than the independent use of either agent. There is of course the alternative possibility of achieving the same result without radiation by the proper combination of antibiotics. Experimental studies in this laboratory and others *(3, 10)* have shown that improved storage life of fresh meats can be obtained by the use of radiation and chlortetracycline as well as oxytetracycline. The present report describes the results of an investigation of some limiting factors involved in the combined use of antibiotics and radiation in the preservation of fresh sliced beef, *viz.*, effective dose ranges of antibiotic and radiation as well as the influence of some packaging films on microbial growth in beef.

MATERIALS AND METHODS

Application of antibiotics. Beef round steaks 1.3 cm in thickness were cut into circular portions weighing 5 to 60 g. All samples in each experiment were cut from the same slice of meat. Weighed portions of meat were packaged as specified in one of the following films: polyethylene (film thickness, 4 mils), Saran Wrap made by the Dow Chemical Company, Midland, Michigan, and MSAD No. 80 cellophane manufactured by the Du Pont Company, Wilmington, Delaware. All meat was polyethylene wrapped unless otherwise specified.

Appropriate amounts of antibiotic in solution were introduced directly into the packages containing meat to yield the desired concentration of antibiotics. 0.2 ml of soln. was used on 5-g meat samples and 1 ml on 40–60 g portions. Sealed packages were rotated and so manipulated as to yield complete exposure of the meat surface to the antibiotic solution. Chlortetracycline (CTC), tetracycline (TC) and oxytetracycline (OTC) were employed. Values given for the amounts of antibiotic on meat are based upon the quantities added and not upon the antibiotic residuals remaining after treatment which were not determined. Irradiation was performed after application of antibiotic to the meat.

Irradiation. The packaged meat was irradiated with X-rays from a General Electric Company 250 kv industrial X-ray machine, model OX-250, operated at 10 ma and 250 kvp. Radiation dose was determined by ferrous sulfate and ceric sulfate dosimetry *(15)*. Other meat samples were irradiated with 2 mev electrons from a Van de Graaf generator.

Storage and evaluation. Treated samples were generally stored at 34° F or 40° F for periods up to 7 weeks during which bacteriological analyses were performed. In a few instances accelerated storage tests were conducted at 68° F. Total viable counts of viable microorganisms were conducted on 5 to 10 g portions of meat comminuted in 100 ml of sterile water for 5 min in a Waring blender. Aliquots of these suspensions were plated in triplicate on trytone glucose extract agar (Difco) and colonies counted after incubation for 72 hr at 77° F. The presence of obligate psychrophilic and thermophilic organisms was not determined.

Limits of chlortetracycline and radiation levels. An experiment designed to determine the useful limits of chlortetracycline concentration and radiation dose was carried out as follows: Two hundred and fifty samples from a fresh beef round were obtained in the form of a cylinder, 10 cm^2 x 0.5 cm, weighing 10 g each. All samples were individually packaged in polyethylene film and randomly distributed into 5 groups each containing 50 samples. The latter were then treated with 0.5 ml of solution containing sufficient chlortetracycline to yield the following amounts of antibiotic.

Sample group	Chlortetracycline, ppm
I	0
II	0.1
III	0.5
IV	10
V	15

All polyethylene packages were then heat-sealed and the antibiotic solution distributed over the entire meat surfaces. After cooling to 39° F, 10 samples from each of the 5 groups of antibiotic levels noted above were irradiated with 0, 100, 200, 300 and 400 kilorads of 2 mev electrons. The processed samples were examined microbiologically after 30 days in storage at 40° F.

RESULTS AND DISCUSSION

Chlortetracycline and X-rays. The application of 7 ppm of chlortetracycline to the surface of fresh beef followed by irradiation with 0.1 megarad of X-rays resulted in marked reductions in microbial counts during storage of the beef for 30 days at 34° F and 40° F (Table 1). These meat samples were also free of undesirable odors. However, meat treated with either antibiotic or radiation possessed an off-odor after 30 days' storage which was not the pronounced spoilage odor observed in the untreated controls. Surface darkening of the beef occurred in all instances which was most noticeable in beef treated only with radiation and penetrated the meat to a depth of about 2 mm. The combination of chlortetracycline and radiation yielded meat with the least amount of surface darkening during storage. This antibiotic appeared to inhibit some of the radiation-induced color changes in meat. The advantages to be gained by antibiotic and radiation preservation of beef are considerably improved by storage at 34° F rather than 40° F as expected (Table 1). Samples of beef treated with chlortetracycline and X-rays and stored 30 days at 34° F were acceptable from the microbiological standpoint, however some improvement in color retention is desirable.

TABLE 1

Microbial counts on beef treated with 7 ppm of chlortetracycline and 0.1 megarad of X-rays then stored at 34° F and 40° F

Treatment of beef	Microorganisms x 10^6/g meat[1]		
	Days in storage		
	0	15	30
Meat stored at 34° F			
Control	0.03	60	100
Chlortetracycline	0.03	0.1	10
X-rays	0.03	0.7	1
Chlortetracycline + X-rays	0.03	0.76	0.4
Meat stored at 40° F			
Control	0.06	100	200
Chlortetracycline	0.06	0.4	30
X-rays	0.06	2	40
Chlortetracycline + X-rays	0.06	0.1	8

[1] Polyethylene wrapped. The values given are means of 5 replicates from 10 samples (60 g) at each parameter.

The comparative effects on microbial counts in beef of varying concentrations of chlortetracycline and radiation doses were determined by employing accelerated storage conditions (Table 2). Comparable microbial counts were obtained with 7 ppm of CTC plus 10,000 rads and irradiation with 100,000 rads in the absence of CTC. Maximum microbial inhibition was observed at the highest levels of each agent, viz., 7 ppm of CTC and 0.1 megarad of X-rays. On the basis of these results, the independent application of CTC would require more than 7 ppm to achieve the preservative effect of 0.1 megarad of X-rays.

TABLE 2

Effect of chlortetracycline concentration and X-ray dose on microbial counts on beef

Irradiation (megarad)	Microorganisms x 10^6/g meat[1]		
	Chlortetracycline, ppm		
	0	1	7
0	500	13	0.8
0.01	17	5	0.5
0.1	0.4	0.3	0.1

[1] Polyethylene wrapped. After storage 2 weeks at 34° F and then 24 hr at 68° F.

Comparison of several tetracyclines. Tetracycline (TC), oxytetracycline (OTC) and chlortetracycline (CTC), independently or in combination with radiation, effectively inhibited the growth of microorganisms in beef during storage (Table 3). Maximum microbial inhibition was observed with TC followed by CTC and OTC.

TABLE 3

Comparative effects of several tetracycline antibiotics and X-rays on microbial counts of beef

Irradiation (megarad)	Microorganisms x 10^6/g meat[1]			
	Antibiotic, 7 ppm			
	None	Oxytetracycline	Chlortetracycline	Tetracycline
0	500	2.6	0.8	0.14
0.1	0.4	0.2	0.1	0.02

[1] Polyethylene wrapped. After storage 2 weeks at 34° F and then 24 hr at 68° F.

Comparison of packaging films. Beef treated with 7 ppm of CTC and 0.1 megarad of X-rays and packaged in Saran film contained appreciably lower concentrations of microorganisms after storage than identically treated samples packaged in cellophane and polyethylene (Table 4). This may be the result of a higher degree of anaerobiosis in the Saran-wrapped meat than in samples wrapped in the other films. Polyethylene is permeable to oxygen and the cellophane was not heat-sealed in this case which may

TABLE 4

Influence of packaging film on microbial counts of beef treated with 7 ppm of chlortetracycline and 0.1 megarad of X-rays

Packaging film	Microorganisms/g meat[1]
Saran	200
Cellophane	17,000
Polyethylene	27,000

[1] After storage 11 days at 34° F then 24 hr at 68° F.

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have allowed some oxygen to enter the packages. Other possibilities are not excluded such as a direct inhibition by the packaging material.

Limits of chlortetracycline and radiation levels. Data shown in Table 5 permit a comparison of the efficacy of 10 and 15 ppm of CTC at relatively low levels of X-irradiation. Although 10 ppm of CTC appears to be as effective as 15 ppm, X-ray doses up to 15,000 rads were inadequate to control satisfactorily microbial growth in beef during storage at 40° F for 28 days.

TABLE 5

Microbial counts on beef treated with 10 and 15 ppm of chlortetracycline and up to 15,000 rads of X-rays then stored 28 days at 40° F

X-irradiation rads x 10^3	Microorganisms x 10^6/g meat[1]	
	Chlortetracycline, ppm	
	10	15
0	32 ± 13	39 ± 47
2.5	53 ± 8	120 ± 32
5.0	29 ± 13	97 ± 20
10.0	11 ± 8	9 ± 3
15.0	13 ± 9	8 ± 4

[1] Polyethylene wrapped. Values given are means ± standard deviations of plate counts.

The evaluation of the useful upper limit of the dosage of ionizing radiation was performed with electron beams rather than X-rays because of the much shorter exposure period required with the former. All control samples receiving 0 and 0.1 ppm of CTC and less than 300 kilorads (without CTC) had pronounced putrid odors after 30 days at 40° F. Those samples receiving 300 and 400 kilorads were unacceptable because of radiation-induced undesirable odors. The irradiated meat samples exposed to 2 mev electrons acquired a chocolate brown color which began to disappear 15 min after irradiation and the normal red color was almost fully restored in about 12 hr.

Meat treated with 0.5 ppm of chlortetracycline and 100 or 200 kilorads contained exclusively yeast populations which were consistently lower in samples receiving 200 kilorads (Table 6). The upper limit of chlortetracycline concentration appeared to be 10 ppm since 15 ppm of the antibiotic did not show any greater reduction in the number of microorganisms of the treated beef samples receiving 200 kilorads of 2 mev electrons (Table 6).

TABLE 6

Microbial counts on beef treated with chlortetracycline and 2 mev electrons then stored at 40° F for 30 days

Irradiation rads x 10^3	Microorganisms x 10^6/g meat[1]		
	Chlortetracycline, ppm		
	0.5	10	15
1	188 ± 18	85 ± 8	.....
2	30 ± 10	10 ± 8	7 ± 7

[1] Polyethylene wrapped. Values given are means ± standard deviations of plate counts.

The above data show that the useful limits of chlortetracycline concentration were 0.5 to 10 ppm and the most suitable radiation dose was 200 kilorads.

Although no attempt was made here to determine whether organisms acquired resistance to antibiotics and ionizing radiation, others have reported *(15)* that organisms of the *Pseudomonas* and *Achromobacter* groups manifested some increase in resistance to tetracyclines.

Acknowledgment

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A Statistical Survey of pH Variation and Sodium Content of Tomatoes*

(Manuscript received June 13, 1960)

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SUMMARY

pH values of California tomatoes were measured before and after peeling using steam and lye as the peeling medium. Lye peeled tomatoes do not increase pH values as compared to raw tomatoes. The core of a tomato affects the pH, and when the core is removed the pH of the tomato is slightly lower. The sodium pickup from lye peeled tomatoes was slightly higher than from steam scalded tomatoes. Citric acid does not lower the pH value of peeled tomatoes. There appears to be no correlation between sodium content, pH and total solids of tomatoes based on a statistical analysis.

During the development of methods and machinery to mechanize tomato peeling and coring, utilizing lye as the peeling medium, a study was conducted in 1957 to determine the effect of lye peeling on the pH of the product *(1)*. The measurement of the pH of individual tomatoes before peeling disclosed that isolated California tomatoes could have a pH significantly over 4.5. Gould reported the effect of seasonal variation of the pH of tomatoes citing factors such as variety, maturity, geographical areas, etc. that influence pH values *(2)*. The work presented here represents a statistical analysis of measurements of pH and sodium content of some 5,000 individual tomatoes under various conditions.

EXPERIMENTAL METHODS

A Beckman Model "G" pH Meter was used to measure the pH values. Individual tomatoes were blended 15 seconds in an Osterizer before pH measurement. Aliquots (100 ml) from 5 tomatoes were then blended to obtain average pH values. Soluble solids were determined, using an Abbe Refractometer correcting for temperature differences. Total solids were then obtained from the method for soluble solids found in the National Canners Association Bulletin *(3)*. The sodium content was obtained by osterizing the tomatoes and filtering on Whatman No 2 filter paper. The filtrate was then placed in a Beckman DU Flame Photometer set at 589 millimicron sodium wave length. The transmission was obtained and plotted against the standard curve of known sodium content. The results were then reported in ppm of sodium.

RESULTS

Table 1 compares the pH values and frequency distribution for steam scalded and lye peeled tomatoes. Only firm tomatoes were utilized in this test work. Citric acid was used after peeling, and the effect of this acid on the pH values is included in this table. The juice was drained off the processed tomatoes prior to measuring the pH value.

Sodium content (ppm) was determined on raw, steam scalded, and lye peeled tomatoes. This information is given in Table 2. Distilled water was used in place of juice on both the steam and lye peeled tomatoes that were processed.

Table 3 compares the pH values of raw tomatoes with and without cores.

TABLE 1
pH values of tomatoes in California

Steam scalded

Tomato pH	Raw	Peeled	Processed
Low	4.24	4.05	4.02
High	4.46	4.56	4.39
Average	4.34	4.35	4.18
% over pH 4.5	2.3	10	0.0
N =	40	40	20
σ =	0.08	0.112	0.09

Lye peeled

Tomato pH	Raw	Peeled	Citric acid	Processed
Low	3.90	4.10	4.02	4.05
High	4.82	4.69	5.03	4.60
Average	4.41	4.34	4.39	4.23
% over pH 4.5	27	10	23	0.02
N =	355	100	240	313
σ =	0.147	0.127	0.153	0.09

TABLE 2
Sodium analysis on tomatoes (ppm/tomato)

Raw		Steam peeled		Lye peeled	
Low	30	Low	30	Low	30
High	75	High	130	High	180
Average	46	Average	80	Average	86
N =	100	N =	100	N =	100
σ =	17.6	σ =	20.3	σ =	38

TABLE 3
Effect of core on pH of tomato

	Core	Tomato less core
Low	4.01	4.0
High	4.6	4.43
Average	4.32	4.27
N =	50	50
σ =	0.119	0.09

A scatter diagram (Figure 1) was prepared to determine the relationship of sodium content to pH in lye peeled tomatoes. A correlation coefficient (r) approaching 1.0 indicates good correlation between variables. Each small block represents one measurement.

Total solids and pH values of raw tomatoes are shown in the scatter diagram in Figure 2. This was done to determine if a tomato at a high pH value also had a high total solids content.

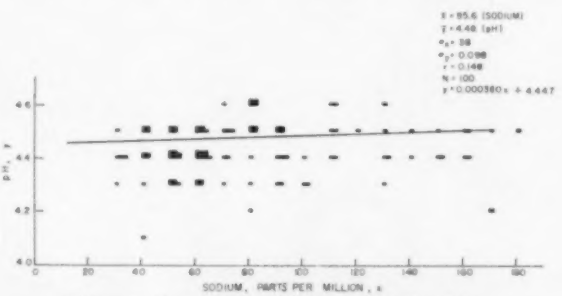

Figure 1. Lye peeled California whole tomatoes. (Scatter diagram)

* Presented at the Twentieth Annual Meeting of the Institute of Food Technologists, San Francisco, California, May 17, 1960.

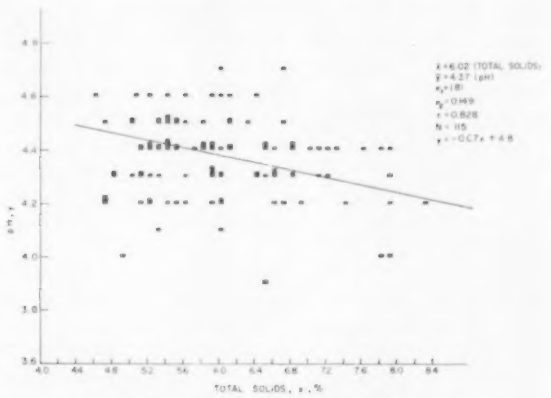

Figure 2. California raw tomatoes.
(Scatter diagram)

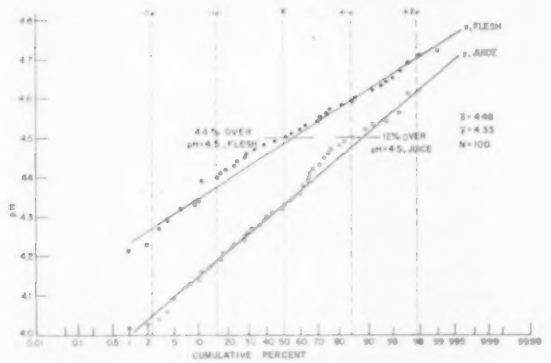

Figure 3. pH values of California tomatoes.
(Juice and flesh of same unpeeled tomatoes)

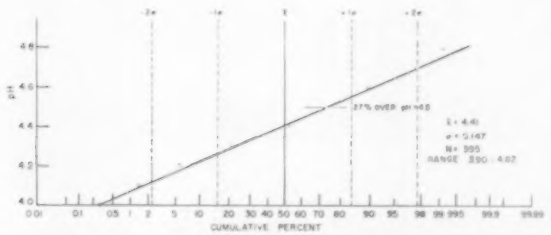

Figure 4. pH values of California tomatoes.
(Raw whole tomatoes)

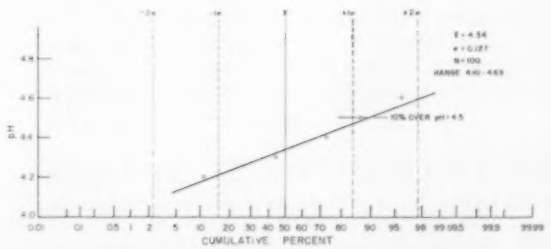

Figure 5. pH values of California tomatoes.
(Lye peeled tomatoes)

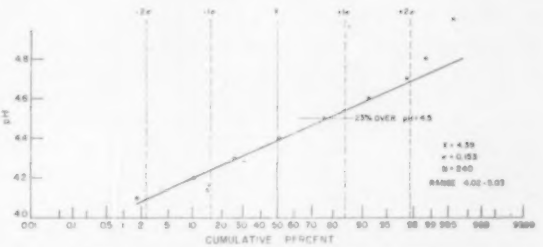

Figure 6. pH values of California tomatoes.
(Lye peeled—sprayed with pH = 3.0 citric acid)

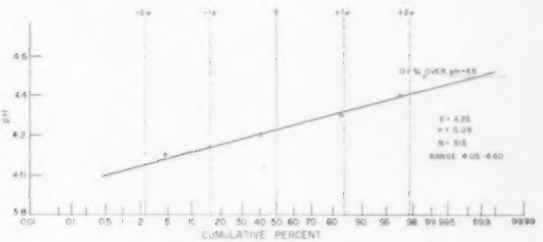

Figure 7. pH values of California tomatoes.
(Processed tomatoes—juice drained)

Figure 3 gives the pH values of juice and flesh of unpeeled tomatoes. This information is presented in probability coordinates in which the arithmetic mean ($\overline{X}$) is found at the 50% level; 14% on either side of this value will give one standard deviation.

The frequency distribution of pH values of raw whole tomatoes is shown in Figure 4. By plotting the cumulative per cent in probability coordinates the arithmetic mean and standard deviation may be readily obtained.

Figure 5 gives the distribution of pH values of lye peeled tomatoes.

Some tomato canners have been using citric acid after the fruit has been lye peeled. The results of using citric acid are shown in Figure 6, giving the distribution of the pH values of tomatoes treated with citric acid.

The frequency distribution of the pH values of processed tomatoes is given in Figure 7. The juice was drained off the tomatoes prior to measuring the pH values.

DISCUSSION

Results in Table 1 demonstrate there is no significant difference in pH values of tomatoes peeled by steam or lye. The average pH value of lye peeled tomatoes is less than the pH value of raw tomatoes. This may be explained by referring to Table 3 where the pH of tomatoes without the core is lower than with the core. The pH values of lye peeled tomatoes were measured after the core had been removed. Processed tomatoes both from steam scalded and lye peeling showed pH values of 4.5 or lower. Tomato juice or puree added to canned tomatoes may aid in keeping the pH below 4.5. Since the tomato has an excellent buffer capacity, citric acid does not appear to lower the pH value of lye peeled tomatoes as compared to pH of raw tomatoes.

The sodium analysis in Table 2 demonstrates a considerable range in sodium content in steam scalded and lye peeled tomatoes. No lye was used on the steam scalded tomatoes, yet the sodium values were found

to be much higher than in the raw tomatoes. The sodium pickup from lye peeled tomatoes was slightly greater than that from steam scalded tomatoes.

The least squares method was used to determine the degree of correlation for sodium vs. pH values of lye peeled tomatoes in Figure 1. The coefficient of correlation (r) was quite low indicating a poor correlation between sodium content and pH values.

The scatter diagram in Figure 2 demonstrating the effect of total solids and pH values on raw tomatoes indicates the poor correlation. One cannot obtain total solids if given pH values with any degree of accuracy, but given total solids one may predict pH values within 0.5 pH unit.

The results shown in Figure 3 for pH values of locular juice compared with the flesh, show that the pH value of the juice is lower than the flesh. Apparently more malic and citric acid are present in the locular juice than in the flesh of the tomato.

Information in Figure 4 on pH values of raw tomatoes shows a range of 3.90 to 4.82 with an average value of 4.41. The average pH value of raw tomatoes was found to be 4.47 in 1957. Studies have been conducted by the University of California and the National Canners Association to determine exactly what causes increases in pH values of raw tomatoes *(4)*. Irrigation appears to have no significant influence on pH of fresh and canned tomatoes. The increase in pH values due to ripening was significant at the 99% probability level.

The pH values of lye peeled tomatoes given in Figure 5 indicate that lye does not influence the pH value of firm tomatoes. By comparing the mean pH of lye peeled tomatoes (4.34) with that of a raw tomato (4.41) the pH value of lye peeled tomatoes is actually lower than the raw tomato. This was explained, since the core was removed on lye peeled tomatoes when the pH was measured. In the case of raw tomatoes the core was not removed. Tests have shown (Table 3) that the tomato with the core had a higher pH value than without a core.

The results of using citric acid to lower the pH of lye peeled tomatoes is demonstrated in Figure 6. By comparing these results with Figures 4 and 5, citric acid does not appear to be beneficial in lowering pH values of lye peeled tomatoes. The buffer capacity of a tomato may affect the influence of citric acid on pH value.

The average pH value of processed tomatoes (4.23) is actually lower than the average pH of raw tomatoes (4.41). Tomato juice added to canned tomatoes may account for lowering the pH value of canned tomatoes after processing.

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The Spoilage of Pacific Coast Rockfish. I.

Spoilage in Ice Storage[a, b]

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College of Fisheries, University of Washington, Seattle, Washington

(Manuscript received June 21, 1960)

SUMMARY

There is no significant difference between the spoilage rates of Pacific rockfish species *Sebastodes alutus, S. melanops* and *S. pinniger* during ice storage. The pattern of spoilage as indicated by the mathematical relationship between organoleptic scores and chemical indexes is similar to that of gadoid fish. Inedible rockfish stored for more than 12–14 days in ice show total volatile acid numbers of 90 or more and total volatile base values in excess of 30, using the vacuum distillation method.

Rockfish *(Sebastodes sp.)* of the family *Scorpaenidae* constitute a significant portion of the annual catch of trawlers fishing off the North Pacific Coast of the United States and of Canada. One species, *S. alutus* (Pacific Ocean perch), makes up the bulk of the rockfish landings. The abundant stocks of other species are very much underutilized. The study described in this paper was part of a program to investigate some of the technological factors which may influence the commercial utilization of rockfish.

Previous work on this problem has been confined principally to preliminary studies on the deterioration in quality of various rockfish species held in frozen storage *(2, 6)*. Some work on the palatability of various species has also been performed *(1)*. The results of these studies indicated considerable variation in both the palatability and the frozen storage life of different species of rockfish. Deterioration of frozen fish held in low temperature storage was characterized by rancidity, toughness, and discoloration of the flesh.

There appears to be no report in the literature concerning the deterioration of rockfish during ice storage. Ice storage of the round rockfish probably constitutes, in all cases, the first important technological factor (or hazard) in the utilization of rockfish for food. The quality or freshness of the fish issuing from ice storage will determine to a large extent, regardless of subsequent processing, the quality of the fish reaching the consumer. Therefore, it seemed logical to investigate this factor first.

This study was designed to provide information on the rate and pattern of spoilage of some commercially important rockfish species when stored in ice. Spoilage was measured by organoleptic and chemical tests.

[a] This work reported herein was carried out under contract with the U. S. Fish and Wildlife Service with funds provided under the Saltonstall-Kennedy Act.

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METHODS AND MATERIALS

Preliminary experiments were carried out, using inshore species *(S. caurinus* and *S. maliger)* to determine the range of values appropriate for the organoleptic and chemical tests to be used in the major investigation. These fish were allowed to spoil in ice storage and were sampled periodically. In addition, cooked fillets were used to provide the taste panel with experience in the general characteristics of spoiling rockfish and to train panel members in the use of the score sheet (Table 1).

TABLE 1
Organoleptic scoring sheet

Score	Characteristics of the cooked fillet		
	Odor	Rancidity	Flavor
5	Fresh, sweet	None	Fresh, sweet slight shellfish flavor
4	Loss of odor but none or only very slight off-odor	Very slight	Loss of fresh sweetness
3	Slight off-odor or slightly rancid	Obvious but not predominant	Insipid, neutral, no flavor at all, or very slightly sour
2	Definitely sour or rancid but not offensive	Definite rancidity	Sour but not nauseating
1	Very sour or rancid, nauseating	Offensively rancid	Very sour, offensive; nauseating, inedible

The species used in the principal experiments were *S. melanops, S. alutus* and *S. pinniger*, which are abundant off the Washington coast. The fish were trawled in grounds off the Washington Coast by the research vessel, M. V. Commando, of the College of Fisheries, University of Washington, and by commercial trawlers. The fish were obtained during the period April–August, 1958. Aboard the vessel, the rockfish were stored uneviscerated in ice and were repacked in the laboratory in an insulated box with fresh ice in a ratio of one part fish to one and one-half parts ice.

Two spoilage runs were made with each species. In the case of *S. melanops* and *S. alutus* the first run was limited to 2 and 3 sampling periods, respectively, but in all other cases the fish were held from 14 to 19 days and were sampled 5 to 6 times during the period. The samples, each consisting of 6 fish, were examined organoleptically and chemically.

The chemical tests consisted of volatile acid (TVA) and volatile base (TVB) determinations using the vacuum distillation method of Tomiyama, da Costa, and Stern *(7)*. This method gives higher values for these substances than the standard steam distillation technique; TVA is expressed as "acid number" in terms of ml 0.01 N NaOH/100 g fish and TVB is expressed as mg N/100 g fish.

The organoleptic examination was made by a panel of 4 or 5 persons who "scored" the cooked fillets according to the scheme outlined in Table 1. The fillets were cooked individually in a beaker, covered with aluminum foil, and partly submerged in boiling water inside a covered pan, for 35 min. No water or condiments were added. Three panel members were trained in the preliminary experiments and operated throughout the study. Only their scores have been used in the calculation of results.

The five-point scale adopted as a scoring guide for the panel was devised on the basis of our experiences during the preliminary experiments and is arranged to encompass the organoleptic quality range from absolute freshness to complete spoilage. An attempt was made to eliminate from the sheet any suggestion of grading the fish into "eating qualities," so that the panel members would be as little influenced as possible by individual preferences. However, it was agreed by all panel members that a score of 2.0 closely approximated the lower limit of edibility for each character.

RESULTS

Results of the preliminary experiments with inshore rockfish species indicated that TVA and TVB values increased during spoilage in a manner roughly similar to the process in other ground fish, such as cod, with which the methods have been widely tested. It was assumed, therefore, that these chemical tests were suitable for use in the full-scale experiments. The scoring system gradually devised during the preliminary experiments was found, in its final form, to cover effectively the range of sensory changes during spoilage. At the end of the preliminary phase, the panel was found to be scoring reasonably consistently, one member with another (usually within ± 0.5 scoring units).

The chemical and organoleptic methods thus developed were applied in duplicate spoilage runs with *S. alutus, S. pinniger* and *S. melanops;* the results are shown in Tables 2, 3, and 4. Applying the criterion that a score of less than 2.0 indicates grossly spoiled fish, it is apparent that all fish in our experiments attained this condition in 11–14 days. All three organoleptic evaluations (odor, flavor, rancidity) showed good agreement on this point. This result is not unexpected, since odor and flavor are closely correlated (r = 1.01) and rancidity is a major determinative factor in each. The chemical data also agree well with this estimate. There is a sharp break between the organoleptically "edible" fish and the organoleptically "inedible" fish in the case of both TVA and TVB results.

Superficially, *S. melanops* appeared to maintain better quality for a longer time in ice storage, than either of the other species. However, this is probably a reflection of handling techniques rather than any intrinsic difference between the species, since *S. melanops* was caught by the research vessel and the other species, mainly, by commercial trawlers.

Because there is such a close relationship between odor score and the scores for the other sensory characteristics, the former may reasonably be considered as representative of the organoleptic results in general. It is convenient to do this since odor scores continue below the "inedible" level where flavor and rancidity scores are few and uncertain. The values for odor score for all species plotted against storage time are shown in Figure 1, where the calculated regression line has been fitted.

TABLE 2
Spoilage of S. alutus

Days in ice	Organoleptic scores			Chemical indexes	
	Odor	Flavor	Rancidity	TVA	TVB
3	4.6	4.6	4.6	23.09	7.07
4	3.7	4.5	4.3	32.98	10.39
7*	3.7	3.8	4.0	23.81	13.66
10	3.2	3.2	3.2	24.26	9.66
13	2.3	2.5	2.9	41.72	18.62
14	1.5	1.7	2.7	71.72	42.65
17	0.5	N.T.	N.T.	82.83	42.78

N.T. These samples were too offensive to taste.
* Indicates mean value of 2 sample batches (i.e., 12 fish).

TABLE 3
Spoilage of S. pinniger

Days in ice	Organoleptic scores			Chemical indexes	
	Odor	Flavor	Rancidity	TVA	TVB
2	4.5	4.7	4.7	31.78	10.40
4*	4.1	4.2	4.2	27.91	10.59
7	3.4	3.5	3.5	36.15	14.95
8	3.5	3.2	3.3	31.23	11.86
11*	2.4	3.1	3.0	73.52	25.74
14	1.8	N.T.	N.T.	200.03	61.50
15	1.3	N.T.	N.T.	113.01	39.80
17	N.T.	N.T.	N.T.	256.54	84.11

N.T. These samples were too offensive to taste.
* Indicates mean value of 2 sample batches (i.e., 12 fish).

TABLE 4
Spoilage of S. melanops

Days in ice	Organoleptic scores			Chemical indexes	
	Odor	Flavor	Rancidity	TVA	TVB
5*	4.4	4.2	4.0	16.73	10.49
7	3.9	4.2	4.4	14.74	10.81
9	3.6	3.6	3.5	20.22	11.74
12*	3.8	3.6	3.9	20.97	11.39
16	1.8	1.7	1.9	81.71	27.70
19	1.3	N.T.	N.T.	118.76	39.77

N.T. These samples were too offensive to taste.
* Indicates mean value of 2 sample batches (i.e., 12 fish).

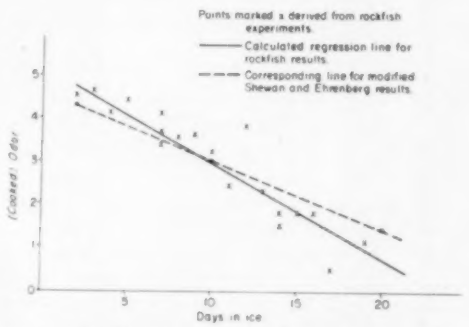

Figure 1. Relationship between odor and storage time.

The scattering of points, particularly around the area "days in ice" = 10–15 days, illustrates the limited value of storage time as a base line aganist which to measure spoilage. Nevertheless, the regression curve has been shown statistically to have the straight line form plotted on the graph (F = 3.02).

Shewan and Ehrenberg *(4)* have derived an equation for the relationship between cooked odor score and storage time for North Sea cod stored in ice. This equation has the form:

$$y = 9.2 - 0.31\ x \quad \text{where } y = \text{cooked odor}, \quad x = \text{days stored in ice.}$$

The organoleptic scale used by these authors has a range 0–10 compared with our five-point range. The approximate form of their equation as it might apply in our case is therefore,

$$y = 4.6 - 0.16\ x.$$

This compares quite closely with the derived equation for our line,

$$y = 5.17 - 0.22\ x.$$

The lines corresponding to both equations are plotted in Figure 1. Two factors affecting the Shewan and Ehrenberg equation are not included in the reconstructed line plotted in Figure 1 because of the mathematical undesirability of modifying approximations by further approximations. These factors should be taken into account in considering the relationship between their line and ours. They are (1) in about half Shewan and Ehrenberg's experiments low scores, equivalent to less than 4.5 on our scale, were given to absolutely fresh, one-day-old fish; (2) the point of inedibility as determined by these authors is close to 2.3 on our scale, whereas we place this point at 2.0. Obviously, correction for both these factors would tend to swing the Shewan and Ehrenberg curve into closer alignment with our line.

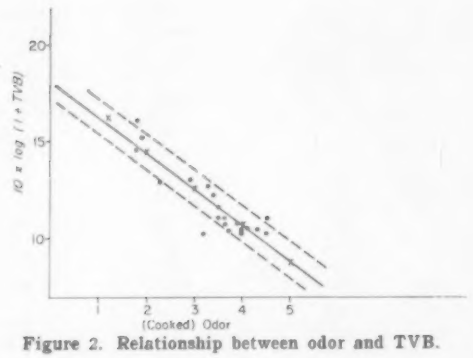

Figure 2. Relationship between odor and TVB.

The relationship between TVB and cooked odor score has been plotted in Figure 2 according to the method used for TVB and cooked flavor in the above quoted paper, in which the value 10 log (1 + TVB) is plotted against flavor score. Since Shewan and Ehrenberg used the Conway Plate Diffusion method and we used the method of Tomiyama *et al (7)* to obtain TVB values, it is not possible to make even the approximate kind of graphical comparison between the two sets of results made in the case of odor and days in ice. However, the general relationship is similar. Most of the points lie within ± 0.5 odor unit (the normal taste panel range) of the fitted line indicating a close relationship between organoleptic score and TVB [correlation between 10 log (1 + TVB) and odor score is 0.927].

The similar straight line relationship between TVA and odor is shown in Figure 3. However, in this case the relationship is not so direct and more points fall outside the ± 0.5 unit limits (r = 0.885).

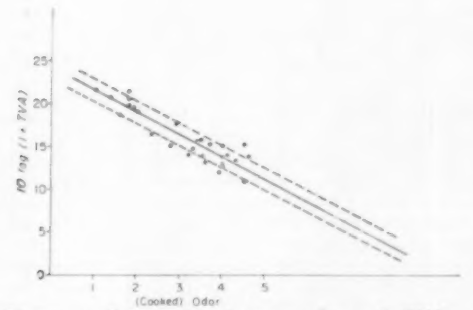

Figure 3. Relationship between odor and TVA.

DISCUSSION AND CONCLUSIONS

It is commonly believed in the fishing industry that certain species of rockfish spoil more rapidly than others. *S. melanops* (black rockfish) is supposed to be one of the more rapidly spoiling types and *S. alutus* (Pacific Ocean perch) among the slower spoiling types. We have found no convincing evidence that any such difference exists in the rate of spoilage of 3 commercially landed species of rockfish when held in ice. In particular, black rockfish did not appear to spoil more rapidly than Pacific Ocean perch.

Moreover, in the admittedly subjective and personal opinion of all panel members, *S. pinniger* (orange rockfish) was the most palatable of the various species tested in the fresh state. From the point of view of palatability and keeping qualities in ice, there seems, therefore, little justification for the continued neglect of rockfish species other than Pacific Ocean perch by the fishing industry of the Northwest.

The rockfish used in our experiments remained of edible quality for close to two weeks in ice storage under good conditions. This is remarkably close to the keeping time reported for trawled gadoid fish (cod and haddock) which have been extensively investigated in this respect *(3)*. Indeed, there is a general similarity in both the rate of organoleptically measured spoilage and in the relationship between the value of certain of the so-called chemical indices of spoilage and organoleptic deterioration. [This latter relationship is, incidentally, a much better measure of the value of a chemical test than the usual "days in ice" comparison, since the latter does not reflect the inevitable variations in storage conditions (such as temperature, bacterial load, etc) from experiment to experiment.]

Thus, it appears that the over-all pattern of spoilage is similar in these two distantly related types of fish. In so stating we do not wish to imply that the same types of odor and flavor change occur, but rather that the rate of change and probably the rate of passage through the various generally recognized quality states (i.e., fresh, good quality, edible quality and inedible quality) are similar. This is of considerable importance to the whole question of so-called objective tests of spoilage, since, unless a similarity exists in the spoilage pattern among different species of fish, such tests can be applied only to a single species. If relationships similar to that noted above between gadoid fish and *Sebastodes* can be established for other commercially important species of fish, the prospects for developing a single universal objective test for fish freshness will be much brighter.

In the case of rockfish both TVA and TVB estimation provides a useful measure of spoilage but TVB would appear to be the more reliable method. A value in excess of 90 for TVA number or greater than 30 for TVB value by the vacuum-distillation method is evidence of grossly spoiled, inedible fish. The organoleptically detectable rancidity which develops during ice spoilage does not appear to be susceptible of measurement by the chemical methods commonly employed to determine rancidity. No correlation was obtained between organoleptic rancidity scores and peroxide number, thiobarbituric acid number *(5)* or iodine number. This may be due, in part, to the difficulty of sampling, since the small amount of fat (1% or less) in rockfish flesh is distributed along the lateral line area in a band difficult to separate from the rest of the fillet.

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Price vs Marbling in the Purchase of Pork Chops[a, b]

(Manuscript received June 4, 1960)

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SUMMARY

A consumer acceptance study was initiated to determine the importance of marbling as a factor in selecting pork chops, and to ascertain the effect of various price differentials on the purchases of highly marbled vs. non-marbled chops. The two types of chops were displayed in a local meat market and were sold at five different price margins, each margin testing 40 customers. In addition, a take home taste test was included to measure the effect of marbling on palatability. A preliminary interview conducted at the market and a telephone interview constituted the means for acquiring customer reactions. Results indicated that a definite preference for unmarbled chops existed among the purchasers; that marbled chops must be reduced considerably in price to induce buyers to purchase the same; that although the taste reaction to marbled cuts indicated a preference for them over the unmarbled chops, this preference was not carried over to the purchase counter.

Do CONSUMERS give more consideration to the price at which pork chops are sold or to those characteristics that may be associated with greater palatability? The taste test which was part of this study indicated that the desirable eating qualities in pork are associated with a fair amount of marbling, i.e., the streaks of fat that are intermixed through the meaty portion of the cuts. But do consumers prefer to buy well marbled pork, or are they principally interested in buying predominantly lean cuts? How would their purchases vary if the same price were charged for both types of cuts, or, if price differences existed? Do their reactions to the cooked meat carry over to their purchases at the retail counter?

To get answers to these questions a study was made of consumer purchases of one type of pork cut; namely, pork chops. This cut was chosen not only because chops are one of the most popular cuts of pork but also because the marked differences between lean and marbled cuts are easily seen by the purchaser.

EXPERIMENTAL DESIGN

The survey was conducted in Madison, Wisconsin, the site being a market, managed by a local meat packing firm and operated for the benefit of its employees. Even though the survey population was restricted to plant employees, there was considerable diversity of occupations and a wide range of incomes and educational levels among the buyers. This cross-section of customers might therefore approximate, at least, those found in markets generally.[c] The fact remains, however, that these customers may be more meat-conscious and more discriminating in their purchases by virtue of their employment in a packing plant.

An important consideration in planning the experiment was to select a retail cut of pork representative of the carcass in terms of marbling content and of consumer demand. Center cut rib chops were chosen to satisfy these prerequisites. All chops were selected on the basis of marbling variation. One set of chops was selected with a high degree of marbling—the other with very little. Factors such as thickness, outside fat, color and size were held as nearly constant as practical for the two sets of chops.

Approximately 40 chops were arranged in each tray with price markers inserted. The trays were placed adjacent to each other in the display case. There were no evidences which might suggest the presence of a survey.

The tests were conducted during 5 periods, with each period including approximately 40 purchasers. Only customers who purchased chops from either of the two trays were included in the study. Of approximately 1800 persons who viewed the meat counter during the survey, 213 purchased pork chops.

A different price schedule was established for each period so as to measure the importance of marbling and price upon consumer purchases. The first period included identical market prices for both trays. During the second period, the lean chops were maintained at the market price and the marbled chops were priced at 4 cents less than the lean cuts. During the third period marbled cuts were 8 cents less in price per pound than

[a] Published with the approval of the Director of the Wisconsin Agricultural Experiment Station, Madison.

[b] We gratefully acknowledge the aid given us by Oscar Mayer and Company, Madison, Wisconsin, who contributed materials and facilities in addition to supplying other co-operation in the conduct of the study.

[c] The composition of the survey population was: 7% had a grade school education only; 28% had some high school education; 39% had completed high school; 15% had some education beyond high school, and 11% had completed college; 23% had a family income under $5000 per year; 34% were in the $5000–$7000 a year bracket; and 43% had family incomes above $7000.

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the lean cuts and in the fourth period 12 cents less. The final period included a reversal of prices with the marbled chops at 4 cents per pound higher than the lean chops. Market price did not vary during the study.

When the participants purchased chops, the interviewer approached and asked why the particular type of chops had been chosen and if they would be willing to answer other questions by telephone conversation at a later date. The telephone call was conducted on the day after the cuts had been consumed.

At the beginning of the fifth period a take-home taste test was introduced. Each participant was given two additional pork chops of the opposite type purchased. The participant was asked to take the pork chops home, cook them identically as those purchased but in different containers, and then make a taste comparison.

RESULTS AND DISCUSSION

The data in Table 1 and Figure 1 summarize the purchases during each period of testing and indicate the influence of both price and marbling on consumer preference. When marbled and lean chops were sold at the same price, there was a predominant acceptance of the lean chops—a preference of 2½ to 1 in favor of the lean chops. This acceptance of lean chops was intensified to 7 to 1 in favor of the lean chops, when the lean chops sold at 4 cents less per pound than the marbled chops (period V). However, as the price was decreased for the marbled chops in periods II, III, and IV, the purchases of the marbled chops increased. A complete reversal of purchases prevailed in period IV (as compared to periods I and V) when the marbled chops were marketed at 12 cents less than the lean chops.

Selection of marbled chops is shown to be influenced by their relation to the price of lean chops, as indicated by these observations:

Price difference was the major reason for selecting marbled chops as indicated by 78% of the participants who bought pork chops in periods II, III, and IV. The remaining 22% of the reasons included appearance, higher quality and "no reason."

Leanness was the answer given by 48% of the participants purchasing the lean chops in periods II, III, and IV. Appearance was attributed as being the reason by 28% of the purchasers. Appearance, as a reason for selecting the lean chops, apparently was closely related to the concept of leanness and was so interpreted in this study, and therefore, leanness possibly accounted for 76% of the reasons for selection. Miscellaneous reasons including higher quality, price and "no reason" were given by the other 24% of the participants. It should be noted that in period II, when marbled chops were 4¢ lower than the lean chops, 81% of the participants buying the marbled chops gave price as their reason for selection. This can be compared to the reverse condition prevailing in period V when the lean chops were 4¢ lower. In period V, 57% of the lean chop buyers said that price was the major reason for their purchase.

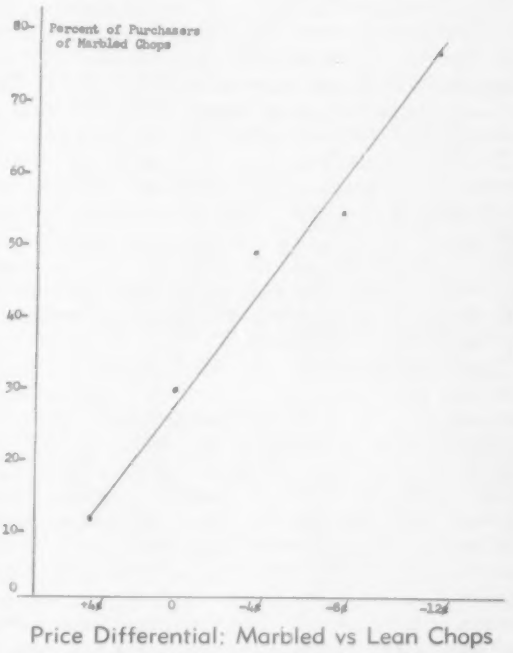

Figure 1. Change in the acceptance of marbled chops over the unmarbled chops as price differentials between the types increase in favor of marbling. (The straight line has been approximated along the five points to show the existing relationship).

In the telephone interviews, 49% of the participants said that too much fat was the main criticism of their usual retail purchases of pork. Of this 49% group 61% purchased lean chops. For those participants (51%) who did not criticize pork because of fatness, 55% of them purchased lean chops. Since the marbled chops were less expensive during 3 of the 5 periods of the survey, the results would suggest that price was more influential than the desire to avoid the extra fat which marbled chops carried.

TABLE 1

Number and percent of purchases of marbled and lean cuts of pork at certain price differentials—Madison market—1957 [1]

Period	Price		Total No purchases	Purchases of marbled chops		Purchases of lean chops	
	Marbled	Lean		No	%	No	%
I	Market	Market	41	12	29	29	71
II	−4¢	Market	45	21	47	24	53
III	−8¢	Market	42	23	55	19	45
IV	−12¢	Market	45	34	76	11	24
V	Market	−4¢	40	5	12	35	88
Totals			213	95	45	118	55

[1] In period I both types of cuts sold at the same price called "market price." In subsequent periods one of the cuts sold at 4, 8 or 12 cents under the price of the competing cut.

No relationship was observed when comparing the size of family to type of pork chops purchased. There was, however, a relationship between the level of education and the selection of marbled chops. The per cent of marbled chops bought decreased with an increase in the educational level of the purchasers.

The occupational group consisting of laborers (70% of the survey participants) purchased the marbled chops 46% of the time. This closely paralleled the average of 44% for all purchasers as indicated in Table 1. In contrast, the office workers group selected the marbled chops only 31% of the time. This group may be less price conscious and more lean conscious regardless of price difference.

Take home taste test. For the purpose of a home taste test each participant was given two additional pork chops of the opposite type purchased with the instruction that these be cooked identically to those purchased. There was indication that the participants in the taste test preferred the marbled pork chops over the lean ones. Of the 83 home taste participants,[d] 62% preferred the marbled chops, 18% preferred the lean chops and 20% indicated no preference. The participants preferring the marbled chops gave tenderness as the reasons 55% of the time, juiciness 51% and flavor 43% for their preference.[e] Other reasons included "tastier," "better texture," "firmness" and "less greasy." Those who preferred the lean chops mentioned tenderness 40% of the time, juiciness 40% and flavor 33%.[e]

A total of 42 participants in the taste test were interviewed by telephone—27 of them liked the marbled chops better than the lean and 15 preferred the lean chops. Twenty-four of those preferring marbled chops stated they were willing to pay on the average of 7¢ per pound more for the marbled chops. Twelve of the 15 interviewees who preferred the lean chops said that they would pay 5¢ per pound more for the lean chops. Little confidence can be placed in such answers, for the actual purchases which were made in the first part of this study contradict the claims.

Frying and secondly braising were the two principal methods of preparing the chops. The participants who preferred the marbled chops used the frying technique 59% of the time as compared to 50% for those preferring the lean chops.

[d] Forty-two families were involved in this taste test. Since in most families two persons tasted the chops, the total number of participants in the taste test was 83.

[e] More than one reason per participant accounts for a total value greater than 100%.

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Enzymatic Conversion of Barley Carbohydrate Into Syrup

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(Manuscript received May 31, 1960)

SUMMARY

Various combinations of amylolytic enzymes have been used as a means for the conversion of whole barley into syrup. The hydrolysis products have been determined quantitatively indicating that the composition of the syrup can be varied over wide limits by the proper selection of enzymes and conversion time.

By using a portion of the beta amylase naturally present in barley good syrup yields can be obtained with as little as 0.5% of a wheat bran culture of *A. oryzae* or by the use of 0.1% commercial enzyme. Preliminary results indicate enzymatically converted barley syrup should compete favorably with corn syrup in Montana.

BARLEY PRODUCTION has increased in Montana in the last decade as a result of the restriction on growing wheat. This increase in production has necessitated searching for new outlets to utilize barley. Converting barley into syrup appeared to offer the greatest potential. There is a large market for syrup in the West Coast States.

In order to compete with corn syrup which is now supplying this demand it would be necessary to have either a less expensive material or one which offered some advantage over corn syrup. Since the conventional process for making syrups of this type is by the acid hydrolysis of starch, the first study was made on the possibility of producing barley starch for conversion into syrup *(4)*. Although high quality barley starch was produced, the starch yields and processing difficulties did not make this process look too attractive. Direct acid hydrolysis of whole grain is unsatisfactory because of low yields and the formation of flavor producing substances. However, since barley contains substantial amounts of beta amylase, it was considered possible that by using this enzyme only very small additions of added enzyme would be required to obtain good syrup yields. This might reduce conversion cost sufficiently to make it competitive with acid conversion. Furthermore, it should be possible to obtain wide variations in the sugar composition of the syrup by proper selection of enzymes used. In view of recent interest in the candy industry for a high maltose syrup, it was considered possible to prepare enzymatically a product which might have more desirable properties than the conventional acid converted syrup. This work was conducted to test these theses.

MATERIALS AND METHODS

Barleys used. All of the barley used in this work was barley of known history produced by the Department of Agronomy at Montana State College. The two strains studied were Compana and Betzes which are well adapted to Montana.

Enzyme sources. Three laboratory cultures *Aspergillus oryzae, Aspergillus niger* NRRL 330, and *Bacillus subtilis* were grown on wheat bran using the procedure described by Hao *(6)*. The *Aspergillus oryzae* and *Bacillus subtilis* were commercial cultures.[a] The beta amylase was obtained by mixing ground barley in a ratio of 1:10 with tap water, allowing to stand for 8–12 hr and then decanting the amount of extract, corresponding to the indicated percentage of original barley. The other enzymes were from commercial sources.

Determination of liquefying power of thinning agent. The liquefying power was determined by adding various amounts of enzyme to a 10% barley mash, holding for 1 hr at 75° C, and determining the relative viscosity by means of flow time from a special pipette.

Determination of enzyme activities. The alpha amylase activity of the various preparations was determined by a modification of the Wohlgemuth method *(9)*. Beta amylase activity was determined by the method described by Bernfeld *(2)*. Maltase activity was determined as described by Sumner *(11)*.

Preparation of barley mashes. Sufficient ground barley was added to cold tap water, the required amount of thinning agent added and the mixture heated to 75–80° C with good agitation. After holding for 1 hr the mash was either cooked for 30 min at 15 psi or held at 75–80° C for one additional hour. The mash was then cooled to 55° C, the converting agents added and the mixture held at this temperature for 16 hr unless otherwise indicated. The residue was then removed by filtration and the wort examined for reducing sugars.

Determination of maltose equivalents. The ground barley was analyzed for total carbohydrates by acid hydrolysis *(1)* and the reducing sugars determined by the method of Sumner *(10)*. The maltose equivalent was calculated from the reducing power of the wort and expressed as % carbohydrate converted to maltose. Since enzymatic hydrolysis usually produces more maltose than glucose this was considered a more satisfactory expression than dextrose equivalent for this work.

Determination of kinds and amounts of sugars present. The sugars from the wort were chromatographed on paper using the procedure described by Gordon *(5)*. The various sugars were eluted from strips cut from the chromatogram and the concentration determined by the method of Dubois *(3)*. Maltotriose was identified by the extended action of alpha amylase which produced only glucose, maltose and the original maltotriose when chromatographed. The sugar designated as panose failed to hydrolyze with alpha amylase. The Rf indicated it to be a trisaccharide and it could be either panose or isomaltotriose. No attempt was made to establish which one was present.

RESULTS AND DISCUSSION

Effect of thinning agent on mash viscosity. In order for direct enzyme conversion to be successful it is necessary to use the highest possible mash strength consistent with good conversion. If the starch is sufficiently liquefied before cooking, a much more uniform mash is obtained and the final conversions are much higher. Preliminary results using *Bacillus subtilis* grown on bran and 3 commercial starch liquefying enzymes indicated that only two of the commercial preparations offered any real promise. These two were examined more thoroughly; the results are given in Table 1.

Both HT-44 and H-39 gave satisfactory results. Since an adequate amount of HT-44 was available and its cost was sufficiently low to make its use feasible, it was decided to standardize on the use of 0.5% HT-44 as the thinning agent.

[a] Made by the Mold Bran Co., Eagle Grove, Iowa.

TABLE 1

Effect of thinning agent on mash viscosity

Enzyme	% by wt	Flow time
H-39	0.03	7.5
H-39	0.04	7.0
H-39	0.05	7.0
HT-44	0.25	10.8
HT-44	0.50	9.5
HT-44	0.75	9.5
HT-44	1.00	9.0

Mash strength 10%.

Enzyme activities of preparations used. Before starting the conversion study it was necessary to have some information on the activity of the enzyme preparations used. These data are reported in Table 2.

Effect of cooking procedure on sugar production. Preliminary studies indicated that barley starch was readily converted into sugars. This suggested that pressure cooking might be unnecessary. To test this theory a series was run using the usual cooking procedure as compared to mashes which were taken from

TABLE 2

Enzyme activity of preparations used

Enzyme source	Alpha units	Beta units*	Maltase
Malt[1]	33	75	
HT-44[2]	105		
Wizyme[1]	150	208	
A. oryzae	100		28**
A. niger	25		17**
Rhozyme H39[3]	1920		
Rhozyme K-2[3]	203	400	
Rhozyme H-33[3]	106	183	

* Expressed as mM of Maltose produced/g enzyme.

** Expressed as time in minutes required for 1 g enzyme to hydrolyze 50% the maltose.

[1] Produced by Wisconsin Malting Co.

[2] Produced by Takamine Division of Miles Chemical Co.

[3] Produced by Rohm and Haas Co.

the thinning step without additional heating. These results are presented in Table 3.

From the data in Table 3 it is apparent that pressure cooking is undesirable as in every case better yields were obtained without pressure cooking. This may be due to the continued action of the liquefying enzyme, which appears to be quite stable at 75–80° C in the presence of substrate.

Effect of mash strength and concentration of liquefying agent on syrup yield. In order to obtain the maximum sugar concentrations consistent with good conversion it was necessary to see how the mash strength and amount of liquefying agent influenced

TABLE 3

Effect of cooking procedure on sugar production

Enzyme combination % of barley used					Pressure M.E.[2]	No pressure M.E.[2]
A. oryzae	*A. niger*	Malt	Wizyme	Infusion[1]		
....	....	....	4	....	61	74
0.5	0.5	....	3	....	66	73.1
1.5	0.5	2	....	....	77.5	80.6
0.5	0.5	....	2	30%	75	85.0
0.5	0.5	2	....	30%	70	82.5

Mash strength 10% and 0.5% HT-44 used in all cases without cooking. Barley was Compana variety.

[1] Infusion is aqueous extract of ground barley.

[2] M.E. is maltose equivalent in all tables.

syrup yields. The results of this study are reported in Table 4.

Although the yields in this experiment were not as high as are usually obtained, it was apparent from the sugar produced and physical characteristics of the mash that concentrations above 15% would not be practical. From these data it was concluded that there was no significant difference between the use of 0.5 and 1.0% liquefying agent. In order to eliminate the

TABLE 4

Effect of mash strength and liquefying agent on syrup yields

Mash strength %	Syrup yields in M.E. using indicated amounts of HT-44		
	0%	0.5%	1.0%
10	22.7	57.0	61.2
15	26.2	60.6	61.5
20	20.0	55.7	55.7
25	.....*	49.0	47.0

Conversion agent 0.5% *A. oryzae*, 0.5% *A. niger* and 20% infusion. Barley was Compana variety.

* Too thick with starch.

effect of mash strength on the remainder of this work it was decided to run subsequent determinations at the 10% level.

Effect of enzyme combinations on yield of sugar. Before making a study of the actual composition of the syrup produced it was considered desirable to screen various combinations for total sugar yield realizing that these values may not be completely valid because of the presence of varying amounts of maltose in some of these preparations. Some of the most promising combinations taken from 106 determinations are expressed in Table 5.

From the data expressed above it was apparent that considerable replacement of the malt could be accom-

TABLE 5

Effect of enzyme combination on yield of sugar

% of enzyme used				M.E. of syrup	
Malt	Wizyme	*A. niger*	*A. oryzae*	Betzes	Compana
10	....	....	....	67.0	65.5
....	4	....	....	61.0	61.5
....	3.5	0.5	....	67.5	67.0
....	3.5	....	0.5	69.0	70.0
....	3.0	0.5	0.5	68.5	69.0
2	....	2.0	....	68.0	72.0
2	....	....	2.0	69.0	74.5
2	....	1.0	1.0	75.0	77.5
2	....	0.5	1.5	78.0	82.0
2	....	1.5	.5	80.0	78.5

Mash strength 10% and 0.5% HT-44 as liquefying agent. Mash cooked after liquefaction to avoid complications of added HT-44 activity.

plished by blending in other enzymes and that the blends were more satisfactory than the malt control.

Effect of barley infusion on enzyme requirements. Since barley contains appreciable amounts of beta amylase which can be readily extracted, a study was made on the amount required to produce optimum results. In order to accentuate the effect of the beta amylase extract, a minimum of other saccharifying agents were used. The results of this experiment are reported in Table 6.

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TABLE 6

Effect of barley infusion on sugar yields

% Infusion added	M.E.
0	41
10	52
20	53
30	55
40	50
50	49

Mash concentration 10% with 0.5% HT-44 as liquefying agent, not cooked and converted with 0.5% Wiszyme. Barley was Compana variety.

These results indicated that 20–30% infusion was ample to furnish all the beta amylase required and that the use of this material could eliminate a great deal of required enzyme.

Sugars produced in the wort by various enzyme combinations. To study the distribution of the sugars produced, an experiment was conducted using a number of enzyme combinations. The sugars in the wort were separated by paper chromatography and determined quantitatively. These results are expressed in Table 7.

TABLE 7

Sugars produced in wort by various enzyme combinations

Enzyme combination in %					% of total sugar in wort					
A.O.	An.	I	M	W	G_1	G_2	i-G_2	G_3	i-G_3	G_n
0.5	0.5	30	....	2	19.3	29.7	11.5	18.7	9.0	10.9
0.5	0.5	30	2	....	20.3	35.3	6.4	10.7	9.0	14.0
0.5	0.5	....	2	....	17.0	32.4	11.8	12.5	7.7	14.5
0.5	0.5	....	....	3	18.7	35.0	13.2	7.5	8.1	12.5
1.5	1.5	20	....	....	40.5	19.6	10.0	8.3	11.2	6.9
1.0	1.0	20	....	....	19.2	21.5	12.0	11.0	10.0	19.2
0.5	0.5	20	....	....	19.5	30.0	6.6	12.3	6.6	19.0
....	....	....	10	....	5.0	50.8	8.0	5.9	7.0	17.7
....	....	20	....	....	3.5	63.0	3.0	T[1]	T[1]	30.0[2]

Barley source was Compana, mash strength 10% liquefied with 0.5% HT-44.

[1] T = trace present.

[2] A considerable amount of high molecular weight dextrin was found in this fraction.

G_1 = glucose, G_2 = maltose, i-G_2 = isomaltose, G_3 = maltotriose, i-G_3 = panose, G_n = higher oligosaccharides, A.O. = *A. oryzae*, A.n. = *A. niger*, I = infusion, M = malt, W = Wiszyme.

From the data in Table 7 it was observed that considerable variation in sugar composition could be obtained by using different enzymes. Although the 10% malt looks promising for the production of maltose syrup it must be remembered that it produces a smaller total yield of syrup, as indicated in Table 5. Therefore, both influences must be considered when choosing an enzyme source. A duplicate of the experiment reported in Table 7 was made using Betzes barley as the carbohydrate source. There was no significant difference, however, and this information is not included.

Effect of conversion time on sugar distribution. Although preliminary work had indicated that a conversion time of 16 hr was satisfactory, it was considered desirable to study the effect of conversion time on the distribution of sugars. This information is reported in Table 8.

From the results in Table 8 it was apparent that under the conditions of the experiment conversion times of less than 16 hr gave distinctly lower total sugars. However, it does point out the possibility of obtaining an infinite number of combinations of sugars and dextrins by varying conversion time along with enzyme source.

Sugars produced by combinations of greatest economic promise. Three combinations previously used which appeared economically feasible were repeated to study more thoroughly the products of hydrolysis. The wort produced was chromatographed as usual except that it was spotted at a higher concentration in order to detect minor constituents. These data are recorded in Table 9.

A reproduction of the chromatographs obtained from these runs is given in Figure 1.

It can be observed that the nigerose content is increased four-fold when only infusion and *A. niger* are used. Undoubtedly, this is a result of synthesis from

TABLE 8

Effect of conversion time on sugar distribution

Conversion time hrs	% of total sugar in wort[1]					
	G_1	G_2	i-G_2	G_3	i-G_3	G_n
4	1.1	40.3	3.3	7.7	1.1	44
8	14.5	30.0	7.1	10.2	3.9	31.0
12	15.7	28.5	5.3	11.8	9.1	28.0
16	19.5	30.0	6.6	12.3	6.6	19.0

Ten per cent Compana mash, liquefied with 0.5% HT-44 and converted with 0.5% *A. oryzae*, 0.5% *A. niger* and 20% infusion.

[1] See Table 7 for nomenclature.

glucose and maltose *(7, 8)*. However, when both *A. niger* and *A. oryzae* enzymes are present the nigerose content decreases. This is the result of the hydrolysis of nigerose by an enzyme system present in *A. oryzae*. This system has been studied in our laboratory and will be the subject of a future report. It is apparent that *A. niger* enzyme is detrimental if a high maltose syrup is desired due to its high maltase activity. Since preparations duplicating our laboratory enzymes might not be available it was considered desirable to check the use of two commercial preparations using our mashing procedure. These results are reported in Table 10.

The data in Table 10 indicated that the use of commercial concentrates gave results approximately equal to those obtained by the use of crude *A. oryzae*. How-

TABLE 9

Sugars produced by selected enzyme combinations

Sugar	% Yield with indicated supplementary enzyme		
	0.5% *A. niger* 0.5% *A. oryzae*	0.5% *A. niger*	0.5% *A. oryzae*
Arabinose	1.5	4.3	2.0
Xylose	1.2	1.6	2.3
Glucose	18.6	14.7	7.5
Nigerose	1.2	8.0	2.0
Maltose	33.5	31.0	51.3
Isomaltose	7.0	9.8	6.0
Maltotriose	10.5	9.8	11.2
Panose[1]	8.0	4.9	5.7
High oligosaccharides	18.5	14.1	15.7

Ten per cent Betzes barley mash, 0.5% HT-44 without cooking and converted using 20% infusion plus indicated saccharifying agents.

[1] This compound gave three glucose molecules on hydrolysis and was not acted on by alpha amylase but not identified in any other manner.

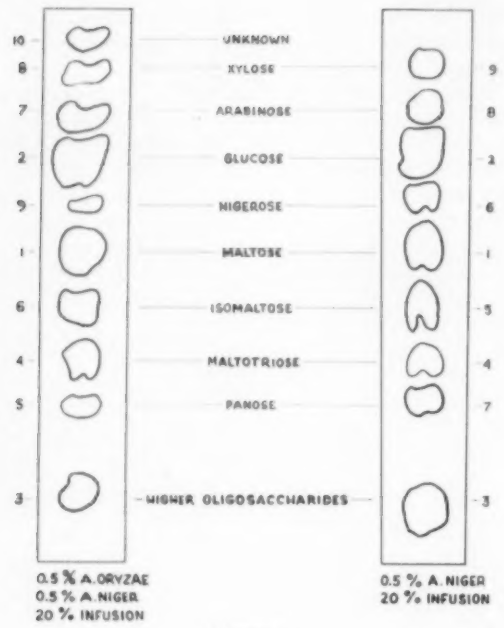

Figure 1.

ever, it was observed that nigerose appeared to be absent indicating either no synthesis or complete hydrolysis by these enzyme concentrates. The latter is the most probable explanation since unpublished work in our laboratories has indicated the presence of nigerose in the form of a polysaccharide in the barley used for this investigation.

Economics of producing barley syrup by enzymatic conversion. The estimated cost of producing syrup from barley in Montana reported in Table 11 has been made using figures based on current costs. However, these calculations have been made without the benefit of a pilot plant operation and may be subject to some revision.

To the above costs it would be necessary to add taxes, depreciation, freight and profit. These figures would vary widely with plant size and location so no attempt has been made for their calculation. Actual cost figures on acid conversion were not available to the author. Corn syrup is made from corn starch and since the selling price of the starch and syrup are usually about the same, one would conclude that the actual cost of acid conversion is equal to the cost of drying the starch plus the increase in revenue due to the incorporation of 20% water. In view of the present quoted price of 7.3¢/lb for corn syrup, it would appear that enzymatically produced barley syrup would be able to compete economically with corn syrup in Montana.

TABLE 10

Sugars produced by commercial enzymes

Sugar	% yield with indicated supplementary enzyme	
	0.3% R-33	0.1% K-2
Arabinose	4.0	2.4
Xylose	1.6	T[1]
Glucose	9.0	9.5
Maltose	56.0	50.0
Isomaltose	7.3	9.5
Maltotriose	4.9	4.0
Panose	T[1]	3.0
Higher oligosaccharides	16.3	21.5

Ten per cent Betzes barley mash, 0.5% HT-44 without cooking and converted with 20% infusion plus indicated enzymes. Maltose equivalents for R-33 and K-2 were 67.7 and 66.3 respectively.

[1] Trace.

TABLE 11

Estimated cost of production of syrup by enzymatic conversion of barley in Montana

Based on processing 100 lb barley from which 75 lb of syrup containing 80% solids and 35 lb of 28–30% protein dried grains are recovered

Steam	$0.25
Power	.25
Labor	.70
Enzyme[1]	.30
Decolorizing carbon	.30
Filter cell	.10
Barley	1.40
Total	3.30
Less 35 lb 30% protein	.70
Total	2.60
Cost of syrup 3.5¢/lb	

[1] Using lowest enzyme concentration found adequate.

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Analysis of Headspace Gases in Canned Foods by Gas Chromatography[a]

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American Can Company, Research and Development Department, San Francisco, California

(Manuscript received May 31, 1960)

SUMMARY

A method is described for determining microquantities of nitrogen, oxygen, carbon dioxide and hydrogen by means of equipment modified to incorporate a two-stage column and two thermal conductivity detectors in a gas-solid chromatographic separation apparatus. The necessary modifications may be made with most gas chromatography equipment. Argon is used as the carrier gas and silica gel and molecular sieve as the adsorbents.

NITROGEN, THE PRINCIPAL GAS normally present in canned foods during storage, is associated with lesser quantities of carbon dioxide and hydrogen. Oxygen included in the container at time of closure is initially dissipated by container corrosion and product oxidation. Departure from this normal pattern can serve as an important criterion of changes within the container. The composition of headspace gases may indicate bacterial spoilage, container corrosion, or product deterioration.

The composition of headspace gases is also important in the case of canned products which require initial low oxygen levels for their keeping quality. Tutton and Coonen *(10)* emphasized the detrimental nature of oxygen in many canned food products and described the methods available for reducing the oxygen content in canned foods. Carotenoid breakdown in stored dehydrated carrots was shown by Mackinney *(5)* to be caused by molecular oxygen.

Large numbers of gas analyses are carried out routinely for packing control of oxygen sensitive foods. Still other analyses are used to detect and investigate the cause of abnormal conditions in canned and packaged food products. The need for gas analysis methods which are both rapid and sensitive is clearly evident. Variations of an Orsat-type apparatus had been previously used for these analyses in this laboratory. Since the sensitivity of this method was limited by sample size, minor constituents in small samples (i.e., 10 ml) could not be accurately determined. The advent of gas chromatography presented an opportunity for developing a better analytical tool for the analysis of micro-quantities of CO_2, H_2, N_2, and O_2 in gases from sealed containers.

Gas-solid chromatography. Mixtures of low boiling gases can be analyzed by gas-solid chromatography. Madison *(6)* employed charcoal for the separation of hydrogen, oxygen, and nitrogen and described a two-stage column for the separation of ethane, propane, and n-butane from these gases. The charcoal stage required approximately 16 minutes for the resolution of hydrogen, oxygen, and nitrogen. Smith *(8)* pointed out that charcoal will completely adsorb carbon dioxide and described a method using silica gel for separating carbon dioxide from nitrogen; however, oxygen and nitrogen are not separated by silica gel. The best adsorbant for resolving oxygen, nitrogen, and hydrogen is a "molecular sieve." This material is a synthetic zeolite.[b] Since this material irreversibly adsorbs carbon dioxide at room temperature *(3)*, it cannot be used alone for this gas mixture.

Workers at Wilkens Instrument and Research *(1)* recently reported the separation of carbon dioxide, oxygen, nitrogen, methane, and carbon monoxide by using a special two-element detector and two carefully balanced columns in series. The first column is silica gel and the second is Linde 13 molecular sieve. The use of helium as a carrier gas precluded including hydrogen in this mixture since the thermal conductivities of hydrogen and helium are relatively close *(4)*.

Brenner *(2)* described a method involving parallel columns for the analysis of mixtures containing oxygen, nitrogen, and carbon dioxide. Silica gel and Linde molecular sieve 5A were used as column materials. This system requires that the division of a sample between the two columns remains in a fixed ratio. If this proportionality is upset by changes in column resistance, the results will disproportionately favor those gases passing through the column with the least resistance.

More recently Murakami *(7)* reported a rapid gas chromatographic method for analyzing mixtures of oxygen, nitrogen, methane, carbon monoxide, and carbon dioxide. The principles of this particular method are very similar to those developed and used in this laboratory for analyzing mixtures of hydrogen, oxygen, nitrogen, and carbon dioxide. This procedure required some interesting and comparatively simple equipment modifications that may be of general interest for canned food analyses and other applications.

EQUIPMENT AND PROCEDURE

Several methods are available for removing gas samples from canned foods for analysis. Stahl *(9)* described a modified Zahm Air Tester that could be used for this purpose. Although this can piercing device may be used for removing a portion of the headspace gas in order to determine its per cent composition, it does not allow for complete removal. Knowledge of total headspace volume is required for ascertaining the total amount of a specific gas that may be present. Complete removal of headspace gases by can piercing devices such as that described by Stahl requires supplemental gas collecting equipment. In addition, the piercing needle must be placed as close as possible to the can wall due to the normal concavity of the end.

[a] Presented at the Twentieth Annual Meeting of the Institute of Food Technologists, San Francisco, California, May 18, 1960.

[b] Manufactured by Linde Division, Union Carbide Corporation.

The gas sampling technique used in our laboratory allows for both a rapid and complete removal of headspace gases. The container is completely submerged in a sink filled with water; the end opposite the headspace is punctured near the double-seam with a sharp ice pick. A water filled inverted funnel, fitted with a serum cap on its stem, is positioned over the container. The can is then inverted so that the headspace gases can escape and displace water in the funnel. The container is then flexed to completely eject the headspace gases. The sample for gas chromatographic analysis is rapidly removed by a 0.25 ml syringe through the serum cap after flushing the syringe several times with sample gas. This syringe is fitted with a Chaney adapter to minimize sampling errors. The volume of the remaining gas is measured by a larger syringe.

The apparatus used was constructed by the authors. Two thermal conductivity cells were mounted in the usual manner in channels drilled in a brass block. The filaments of these two cells served as opposing variable resistances in a bridge circuit and carried a current of 140 ma. The presence of a substance other than the carrier gas produced an imbalance in the bridge circuit which was recorded on a Varian G11A recorder.

The separation was accomplished using a two-stage column operating at room temperature with only two thermal conductivity wires (Figures 1 and 2). Argon was used as the carrier gas at a flow rate of 30 ml per min. The sample was introduced into the system by a syringe via a serum cap. The argon carried the sample onto a 4 inch column of 28–200 mesh anhydrous silica gel.

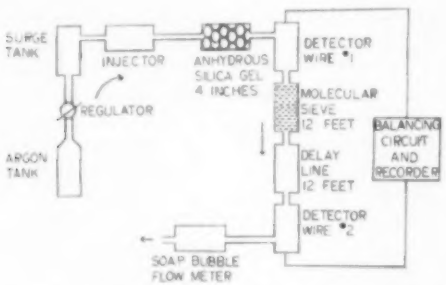


Figure 1. Analytical system for CO_2, H_2, O_2 and N_2.

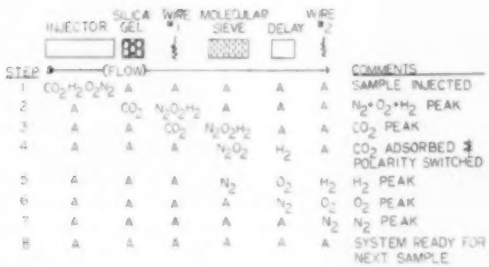

INJECTOR
SILICA GEL
WIRE #1
MOLECULAR SIEVE
DELAY
WIRE #2
STEP
(FLOW)
COMMENTS
1 CO2 H2 O2 N2 A A A A A SAMPLE INJECTED
2 A CO2 N2 O2 H2 A A A N2 • O2 • H2 PEAK
3 A A CO2 N2 O2 H2 A A CO2 PEAK
4 A A A N2 O2 H2 A CO2 ADSORBED ∴ POLARITY SWITCHED
5 A A A N2 O2 H2 H2 PEAK
6 A A A A N2 O2 O2 PEAK
7 A A A A A N2 N2 PEAK
8 A A A A A A SYSTEM READY FOR NEXT SAMPLE

Figure 2. Schematic for separation of CO_2, H_2, O_2 and N_2.

The first thermal conductivity cell was placed at the exit of the silica column. This was followed by a 9 foot Linde 5A Molecular Sieve column (30–60 mesh), a 12-foot time delay section of tubing, and the second thermal conductivity wire. Copper tubing (¼ inch) was used throughout. The two thermal conductivity wires were balanced against each other so that either could serve as the detector or reference. A polarity reversing switch was added so that the recorder deflection could always be maintained in the same direction.

Both columns may be removed from the block and regenerated by heating and concurrently purging them with nitrogen. The short silica gel column may be gently heated for 15 min with a Bunsen Burner. Heating the longer molecular sieve column overnight at 300° F is generally adequate for its regeneration.

RESULTS AND DISCUSSION

The reasons for the particular sequence of detectors and columns deserve comment. Carbon dioxide is irreversibly adsorbed by molecular sieves at the temperature used herein; therefore, it is necessary to detect it as soon as it leaves the silica gel column. Since carbon dioxide is strongly adsorbed on silica gel at room temperature, it is necessary to use only a 4-inch column to separate carbon dioxide from the other gases, which pass through without restriction or resolution.

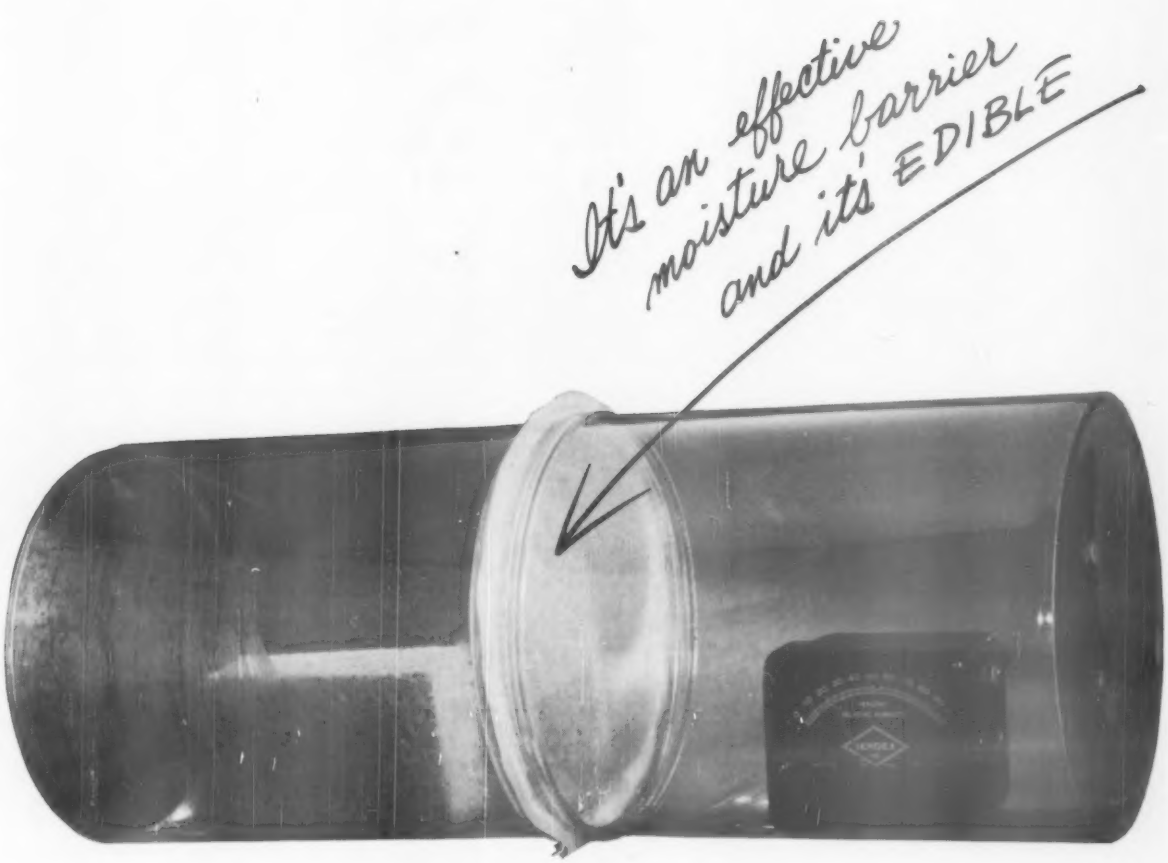
At a flow rate of 30 ml/min the total residence time of carbon dioxide on the silica gel is about 2 min. It was found that less than 2 min were required for the hydrogen to pass through the silica and molecular sieve columns. Empirically, it was found that 12 additional feet of copper tubing after the second column sufficiently delayed the hydrogen arriving at the second detector so that its signal did not interfere with that of the carbon dioxide. It is preferable to make the time delay with unfilled tubing rather than with a longer molecular sieve since the latter alternative would result in too long a residence time for nitrogen and oxygen in the sieve material. An inlet pressure of 25 psig was required for obtaining the desired 30 ml/min flow rate.

The use of only two thermal conductivity wires is advantageous since this is the standard arrangement and does not require additional instrumentation or a special cell design. This same block may be used in conjunction with appropriate columns for gas-liquid-partition-chromatography.

The selection of carrier gas posed several problems, all of which were solved by argon. Nitrogen and hydrogen could not be used for obvious reasons. The lack of sensitive response of hydrogen with helium as the carrier gas precluded its use. The low thermal conductivity of argon allowed it to be successfully used as the carrier gas.

Since the thermal conductivities of oxygen, nitrogen, carbon dioxide, and hydrogen are higher than argon, these gases would each show the same deflection. As the carbon dioxide passed over the first thermal conductivity cell, argon was in contact with the second cell and it was therefore serving as the reference. By the time hydrogen, oxygen, and nitrogen reached the second cell, argon was passing through the first cell, which was then the reference. This alternating role of reference and detector of the two cells, therefore, necessitated the polarity change after carbon dioxide was detected.

A chromatogram showing the separation of a gas mixture containing 39% carbon dioxide, 1% hydrogen, 12% oxygen, and 48% nitrogen is shown in Figure 3. This is typical of separations that may be obtained with the two stage column. By using this arrangement the time for complete analysis is 6 min at a 30 ml/min flow rate.



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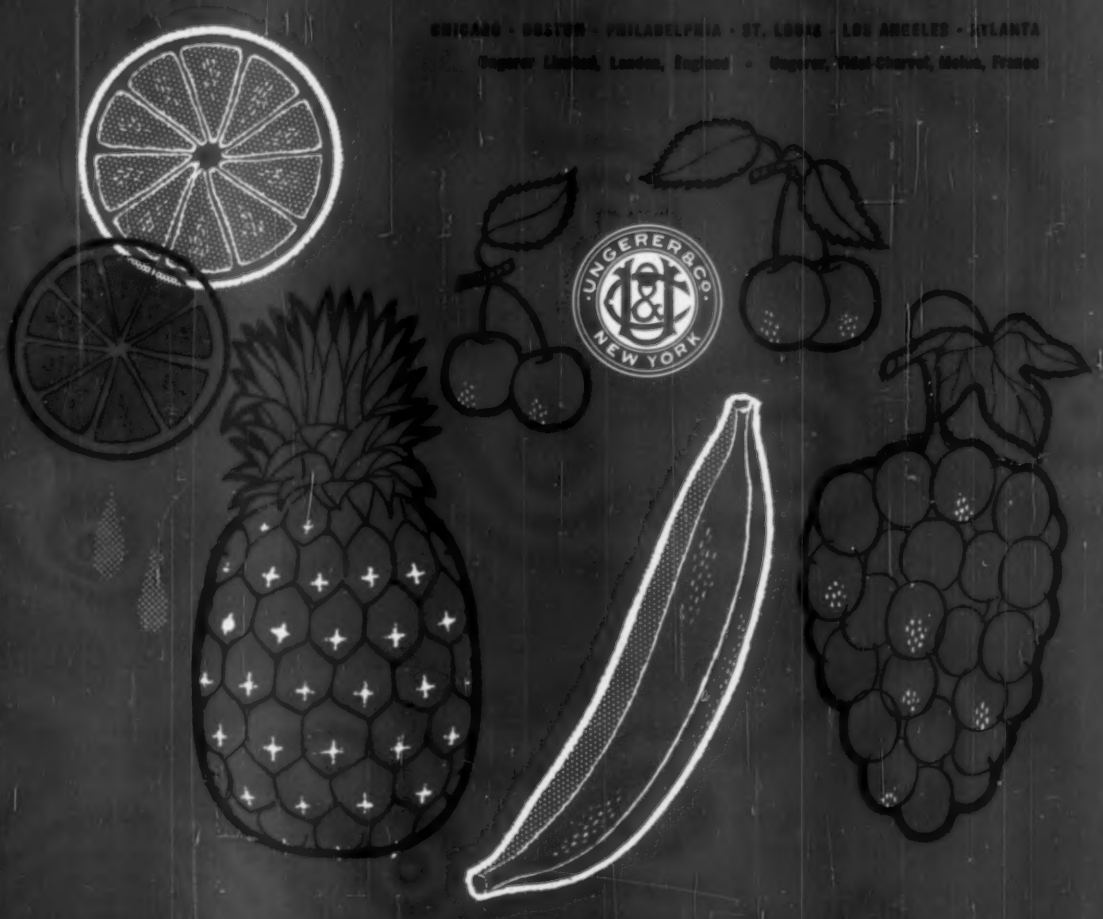

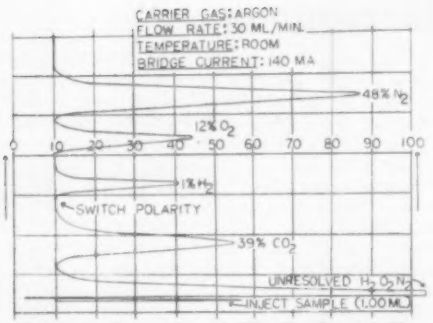

Figure 3. Separation of CO_2, H_2, O_2, and N_2.

Since the response of the detector is not the same for all gases, calibration is necessary. Typical calibration and retention volume data for the 4 gases are summarized in Table 1. The use of argon as carrier gas provides increased sensitivity to hydrogen. This is of particular benefit in corrosion studies.

TABLE 1

Column calibration and retention volumes of hydrogen, oxygen, nitrogen, and carbon dioxide

Gas	Volume	Attenuation	Peak height	Half-width	Calibration factor[1]	Retention volume
	ml		*in*	*in*		*ml*
H_2	0.25	10 X	9.38	0.50	186.6	94
O_2	0.105	1 X	4.02	0.49	18.8	125
N_2	0.39	1 X	8.53	0.73	16.0	157
CO_2	0.40	1 X	5.50	0.75	10.3	34

[1] Calibration factor is the calculated peak area in square inches for 1.00 ml of gas at 1X attenuation.

The accuracy and precision of this sampling technique are shown by the data in Table 2. A gas mixture was collected by mercury displacement and analyzed in triplicate. This mixture, complete with mercury seal, was placed in a sink filled with water. The gases were then released and trapped by the inverted funnel fitted with a serum cap. Samples were removed at 1, 6, and 13 min intervals for analysis.

Normally the gas can be removed from a container and sampled for analysis within one minute. The data in Table 2 indicate that at least 92% of the carbon dioxide can be recovered by this sampling technique. The recovery can be increased by replacing the water with an acidified saturated sodium chloride solution.

TABLE 2

Accuracy and precision of sampling technique

Description	H_2	O_2	N_2	CO_2	Total	CO_2[1]
Collected over Hg	0.72	8.9	33.6	61.2	104.4	.....
Collected over Hg	0.70	8.4	33.4	60.6	103.1	.....
Collected over Hg	0.70	8.8	33.6	60.3	103.4	.....
Average	0.71	8.7	33.5	60.7	103.6	100.0
1 min over water	0.72	9.8	36.8	55.9	103.2	92.2
6 min over water	0.74	10.5	37.3	53.5	102.0	88.2
13 min over water	0.75	11.0	38.1	49.4	99.2	81.5

[1] Percent of total CO_2 recovered.

Although there is some loss of CO_2 by absorption, the method is sufficiently accurate for the intended purpose. It is apparent that the influence of carbon dioxide absorption on the per cent composition of the remaining gases is minimal. The results of the triplicate analyses indicate the accuracy of the gas chromatographic method.

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Dehydrofrozen Apples: Recent Developments in Processing Methods*

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SUMMARY

Improved processing methods for dehydrofreezing apples are described. Procedures are given for use of ambient-humidity drying air instead of the humid air specified in previously-reported work. Through-flow drying was substituted for cross-flow. Three piece sizes and three different varieties were processed under various conditions. Advantages of using an optional blanching step after drying are discussed. A procedure is also given for a blanched nonsulfured product.

DEHYDROFREEZING, the process in which foods are dried to 50% or less of their fresh weight and then frozen, has been described earlier *(3, 4, 9, 10, 11, 12)*. Dehydrocanning is a closely-related process for producing a *canned* product *(7, 8)*. Dehydrofrozen apples are high-quality double-strength stocks suitable for use in pies *(2)*. Since the apples are dehydrated to 50% weight reduction and about 50% volume reduction, costs of container, shipping, and storage are reduced *(4)*. The process for dehydrofreezing apples consists of the following steps:

Preparation of the fruit ⟶
Dip in a soln of SO_2 ⟶ Hold period ⟶
Dry to 50% wt reduction ⟶ Freeze

In previous work *(11, 12)*, apples were dried in a cross-flow dryer. Relative humidity was required to be in the range of 25–30% in the air used for drying. This requirement had two purposes: (a) to cause the sulfur dioxide applied during the dipping operation to diffuse from the surface into the interior of the piece, and (b) to reduce the residual sulfur dioxide content to suitably low levels. Recent tests using a belt-trough dryer *(5)* and a rotary dryer *(9)* indicated that under through-flow drying conditions, satisfactory results might be obtained with ambient-humidity air. Therefore, further tests have been made to determine the conditions under which drying air of ambient humidity could be used, and to determine how the useful range of other processing variables could be broadened. This paper presents and discusses the newer procedures. Its purpose is to guide processors of dehydrofozen apples in three ways: in selection of processing equipment needed; in selection of processing conditions to meet requirements in a particular plant; and in the solution of processing problems arising from variations in variety, maturity, and size of fruit received at the plant.

The use of SO_2 to inhibit enzymatic browning in the drying of apples is an old, well-established practice. Low residual concentrations of SO_2 are desired in the final product when it is consumed, since amounts greater than about 50 ppm are detectable by the average consumer and are often objectionable. One of the objectives of this work was to determine the relative importance of the factors that are critical in changing the distribution or concentration of sulfur dioxide in the apple piece.

Dip solutions made with sulfur dioxide gas are more effective for penetration of apple tissue than are solutions of sulfite salts; however, it is more convenient to use acidified sodium sulfite or bisulfite as the source of SO_2 in the dip solution. The selection of the sulfuring method will probably be decided on the basis of the facilities already available at the processing plant.

If salt and citric acid are substituted for SO_2 in the dip solution *(7, 8)*, a sulfur-free dehydrofrozen product may be produced; however, the double-strength fruit must be blanched prior to freezing. In the present work, blanching procedures were applied to sulfured as well as unsulfured fruits, so that the blanched and the unblanched dehydrofrozen products could be compared.

Piece size or style of cut of apples used in pies may vary in different areas. Most apples of normal size that are canned or frozen for pie use are cut into $\frac{1}{12}$ radial sections, the size considered "conventional" in this and in previous work. In many plants, size-graded fruit is cut according to size into $\frac{1}{8}$ through $\frac{1}{14}$ wedges. Some drying plants produce true slices, or rings, and some produce diced fruit or other special forms. In dehydrofreezing, processing conditions may be adjusted for the style or size of cut produced. Also, it may be necessary to adjust cut size or style, if other measures are inadequate to maintain bright product color.

Discoloration during processing is particularly serious early in the harvest season when much of the fruit is immature. Sorting out immature fruit before processing would aid in reducing the incidence of surface or interior browning in the dehydrofrozen product. However, it is usually more feasible to control the browning of immature fruit by adjusting processing conditions.

METHODS

Raw material. The varieties of apples tested were Winesap, Rome Beauty, and Yellow Newtown. For uniformity, only size-graded fruit of 113-count per 42-lb box was used. The Winesap and Rome Beauty lots were optimum-maturity fruit

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but the Yellow Newtown lot was somewhat immature. All apples were held at 34° F until used.

Processing. Apples were peeled and cored in a hand-operated machine, hand trimmed, and held in a 1% solution of sodium chloride until used, usually a period of one-half hour or less. The apples were cut into conventional 1/12 radial sections (wedges), 1/16 wedges, or 1/2-inch cubes. The cut fruit was placed in a perforated stainless-steel basket and immersed in the dip solution [4] for the desired period. The basket of dipped fruit was drained for 2 to 3 min and then placed in a covered container (except as noted in Table 2 and Figure 3) for the desired holding period. Free liquid was allowed to drain from the fruit during the hold period. The fruit was loaded, 4.5 lb/sq ft (approximately 3 layers deep), onto a tray with a stainless-steel wire-cloth bottom and dehydrated to 50% of original weight in a through-flow dryer (Figure 1). Air flow was about 300 cfm/sq ft and was at ambient humidity. Upflow air was used during the first half of the drying period and downflow during the second half. The air direction was quickly and easily reversed by changing the settings of the 4 dampers in the dryer (see Figure 1). After drying, each tray of double-strength apples was divided into two portions of approximately 1 lb each. One portion was packed into a freezer carton and frozen with forced air at −20° F. The other portion was steam-blanched (at 205° F) before packaging and freezing. All fruit treated with salt and citric acid was steam-blanched at 205° F after drying. Blanch times were adjusted in each case for cut size: 2 min for 1/12ths, 1½ min for 1/16ths, and 1 min for ½ inch dice. The double-strength frozen product was stored at 0° F for later evaluation. Samples of fruit were taken at various stages of the process and were analyzed for sulfur dioxide content by the Monier-Williams *(1)* method. Presence or absence of internal browning was observed by passing a strong light through the slices, or by cutting a number of representative pieces.

RESULTS AND DISCUSSION

Factors governing transfer of sulfur dioxide in apple tissue. The SO_2 content of the fruit is at its peak immediately after dipping and decreases during subsequent operations. The general effect of changes in processing variables on the SO_2 content of apple pieces is shown in Table 1. The SO_2 content and penetration into the fruit can be adjusted by manipulation of the processing variables as shown in Table 1.

Adjustment of the dip concentration was the most effective and convenient method of controlling the initial SO_2 content of the fruit (see Figure 2), although dip time was also important (Figure 3). Raising the dip temperature from 72° F to 100° F only slightly increased the penetration and final level of SO_2 (Table 2).

The sulfur dioxide content of the dipped fruit decreased during holding on open trays (Figure 3) but remained substantially constant when the baskets of slices were held in closed containers to eliminate volatilization. Draining of dip solution during the hold period appeared to be insignificant. However, as the predrying hold period was increased, penetration of SO_2 into the piece was improved and less SO_2 was lost during drying (Table 2 and Figure 4). An addi-

TABLE 1

Effect of processing variables on sulfur dioxide movement in apple tissue

Variable and direction of change	Effect on apple pieces[1]	
	SO_2 content	SO_2 penetration
SO_2 conc in dip, increase	+++	++
Dip time, increase	++	+
Dip temp, increase	+	+
Piece size, decrease	++	++
Hold time, increase	++ [2]	+++
Drying temp, increase	−− [2]	+
Drying humidity, increase[3]	−− [2]	++
Blanch time, increase	− [2]	None

[1] Minus and plus signs indicate a decrease or increase, respectively; greater magnitude of change is indicated by a larger number of plus or minus symbols.
[2] SO_2 content of the dehydrofrozen product.
[3] From results of earlier work.

[4] SO_2 gas was used in preparation of the dip solution only for tests shown in Table 2 and Figure 3. In all other tests, dip solutions were made to the desired strength using one part of sodium bisulfite (assayed as 58.5% SO_2) to one-half part citric acid monohydrate, giving approximately equal weights of SO_2 and citric acid. The bisulfite dip solutions containing 4000 ppm SO_2 had a pH of 2.9–3.0. Sulfur-free dip solutions contained 1% NaCl plus 1% citric acid.

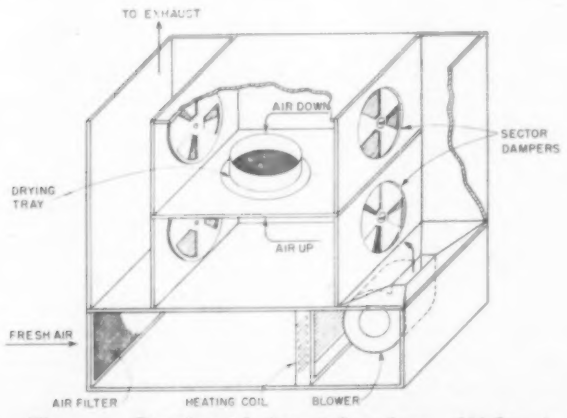

Figure 1. Experimental through-flow dryer. (Airflow is adjusted to either upflow or downflow, by opening the proper dampers).

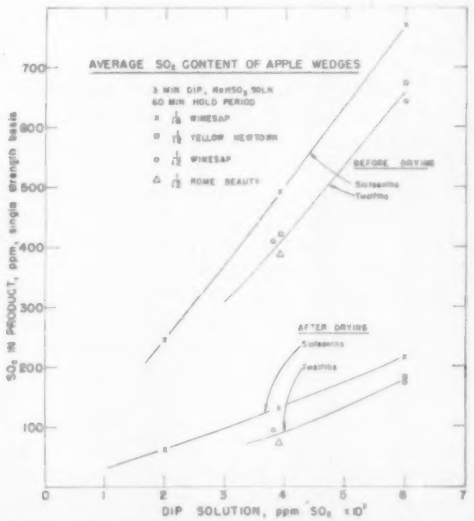

Figure 2. Sulfur dioxide content of apple wedges before and after drying.

TABLE 2

Effect of dip temperatures and hold time on SO_2 content (Winesap, 1/12 wedges, dried to 50% w.r. at 180° F)

Dip conditions			Hold time	SO_2 content, ppm		SO_2 lost during drying
Time, min	Temp, °F	SO_2, ppm[1]	Min	Before drying[2]	After drying[3]	%
2	72	1850	3	280	55	80
2	72	3150	3	375	105	72
2	63	1900	30	155	75	52
2	72	3050	60	205	130	37
2	100	2850	60	220	150	32

[1] SO_2 gas used in the dip solution.
[2] After "open" hold period.
[3] Converted to single-strength basis.

tional benefit of longer hold time was that it was possible to shorten the drying time by using higher drying temperatures, since the apples were better protected by the increased penetration of SO_2.

Losses of sulfur during dehydrofreezing of apples and during baking the product into pies are shown in Table 3. The fractions of SO_2 remaining in the fruit,

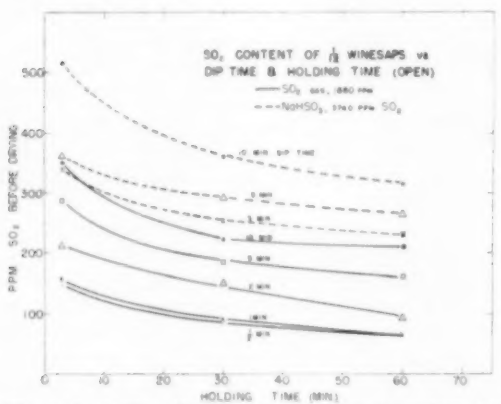

Figure 3. Sulfur dioxide content of apple wedges before drying—effect of dip time and hold conditions.

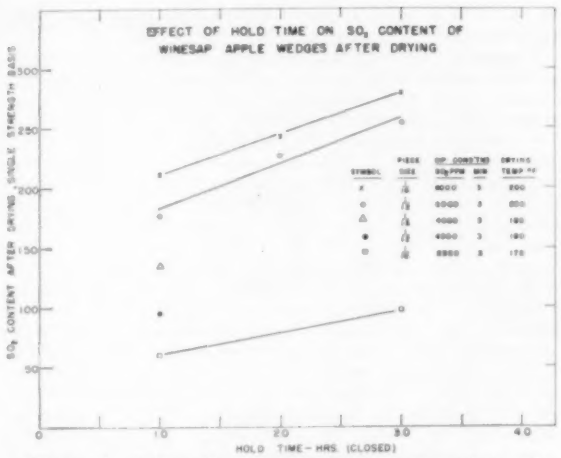
EFFECT OF HOLD TIME ON SO2 CONTENT OF
WINESAP APPLE WEDGES AFTER DRYING
SO2 CONTENT AFTER DRYING, SINGLE STRENGTH BASIS
HOLD TIME - HRS. (CLOSED)

Figure 4. Sulfur dioxide content of apple wedges after drying—effect of wedge size and hold time.

based on the initial SO_2 content after dipping, are as follows: 15–40% after drying, 10–30% after blanching the double-strength fruit, and only 3–10% after baking the dehydrofrozen product into pie. The decimation of the sulfur content during processing and baking is an important fact. It indicates that apple pieces may have a wide range of SO_2 contents after different dipping treatments, and yet the residual sulfur in the final baked product need not exceed the desirable limit. The processor must know how to select and adjust processing conditions to control residual sulfur in the product. For example, high initial sulfur content in the dipped fruit can be corrected by shortening the hold time, by drying at higher temperatures, or by blanching after drying. Conversely, if low-concentration dip solutions are used, or if the fruit is not readily penetrated by SO_2, hold times may be extended, or piece size may be reduced. If the pre-

TABLE 3

Losses of SO_2 in dehydrofrozen apples during processing and pie baking

Test	Variety	Cut[1] size	SO_2 content of apples, "As is" basis											% original SO_2 left
			Dipping		Holding		Drying			Blanching		Baking		
			Time, min	SO_2, ppm	Time, min	Open or closed	Before, ppm	After, ppm	% SO_2 lost	After, ppm	% SO_2 lost	Pie ppm	% SO_2 lost	
1	W	1/12	5	3750	60	O	265	170	68	....	....	25	71	10
2	W	1/12	3	3900	30	O	205	140	66	130	7	....	....	....
3	W	1/12	3	1950	30	O	200	110	73	....	....	....	....	....
4	W	1/12	3	6000	30	C	675	....	....	....	....	....	....	....
5	W	1/12	3	6000	60	C	580	355	69	215	39	....	....	....
6	W	1/12	3	6000	120	C	645	455	65	....	....	....	....	....
7	W	1/12	3	6000	180	C	670	505	62	305	40	70	72	10
8	W	1/16	3	6000	60	C	715	430	70	....	....	....	....	....
9	W	1/16	3	6000	120	C	....	485	....	....	....	....	....	....
10	W	1/16	3	6000	180	C	830	560	66	....	....	85	70	10
11	W	1/16	3	2000	60	C	250	120	76	80	33	....	....	....
12	W	1/16	3	2000	180	C	230	195	58	120	39	10	90	4
13	W	½" D	3	2000	30	O	290	145	75	105	28	....	....	....
14	YN	1/12	3	3900	30	O	340	185	73	105	43	....	....	....
15	YN	1/12	3	6000	30	O	435	215	75	110	49	....	....	....
16	YN	1/12	3	6000	60	C	675	360	73	165	54	30[2]	64	5
17	YN	½" D	2	4000	30	O	680	320	76	110	66	....	....	....
18	YN	½" D	2	2000	5	O	310	85	86	....	....	10	77	3
19	RB	1/12	3	4000	30	C	335	145	78	125	16	20	72	6
20	RB	1/12	3	4000	60	C	....	150	....	100	33	....	....	....
21	RB	1/12	3	4000	60	O	....	....	....	....	....	20[2]	....	....

[1] "D" indicates dice; all others were wedge cut.
[2] Pies made from blanched samples. All other pies were made from unblanched samples.

ceding changes are not practical, drying temperatures must be reduced. The fruit may be blanched after drying to prevent darkening during defrosting. This technique of adjusting processing variables and using them in different combinations may be illustrated by an actual example: The Yellow Newtown apples used in these tests were immature and difficult to dehydrofreeze without browning. Increasing the sulfur content by adjusting the dip and hold conditions, and reducing the drying temperature, corrected the difficulty. However, equally good results were obtained in control of discoloration simply by cutting the fruit into slightly smaller pieces (Table 4). There was marked improvement in penetration of SO_2 in the smaller cut size. Use of smaller cuts offers other advantages, such as shorter drying (see Figure 5) and blanch times, higher packaging density, and improved reconstitution. Use of smaller cuts is suggested primarily as an expedient to maintain product quality in difficult cases; however, it may be found that some users of dehydrofrozen fruit will prefer the quicker-

TABLE 4

Effect of cut size on development of brown centers (Yellow Newtown)

Cut size	Dip		Hold time, min	Drying		Brown centers, %
	Time, min	SO_2, ppm		Temp, °F	Time, min	
1/12 Wedge	3	4000	60	180	45	8
1/16 Wedge	3	4000	60	180	33	0
1/12 Wedge	3	4000	60	170	50	6
1/2" dice	2	4000	30	170	20	0

reconstituting smaller cuts. Substitution of 1/16 wedges for 1/12 cuts is not readily apparent in the baked product.

Drying conditions. Typical through-flow drying curves are shown in Figure 5 for a tray loading of 4.5 lb/sq ft (approximately 3 layers). This is about 3 times the loading normally used in cross-flow drying and approximates that which might be used in drying of apple wedges on a continuous conveyor-belt dryer. Even with the greater loading, drying times with through-flow are about 20% less than with cross-flow.

Our results, obtained with inlet air at ambient humidities of 0.005–0.010 lb H_2O per lb of dry air, show that high-humidity drying need not be the *major* means of controlling the SO_2 content of the dehydrofrozen product. With proper processing conditions, humidity during drying is not critical. Therefore, more freedom may be exercised in selection of drying methods or conditions. Dryers of the through-flow type are excellent for use in this process, but other types of dryers may be found suitable, if properly operated.

Advantages of blanching. Blanching has not previously been considered as a required step* in dehydrofreezing, but the advantages in its use are significant. First and most important, if there is doubt that the SO_2 content or distribution in the double-strength product is adequate to protect against later discoloration, it is good insurance to lightly blanch the fruit after drying and prior to freezing. Another advantage is that 25–30% more double-strength fruit can be packed into a given container if the product is blanched. Blanched fruit reconstituted to 87% of theoretical when soaked 1 to 2 hr in cold water, compared with 78% for unblanched. However, both types reconstituted close to 100% when soaked longer or when reconstituted with heating. If blanching is to be used, the fruit must be overdried only slightly (to about 54% weight reduction) to allow for moisture pickup during blanching. Although blanching is not ordinarily recommended for fruit that softens excessively, a good, blanched, double-strength product was made from firm, early-season Rome Beauty apples, usually considered to be a quick-softening variety. Less softening occurs during blanching of double-strength apples than when the fruit is in the undried form.

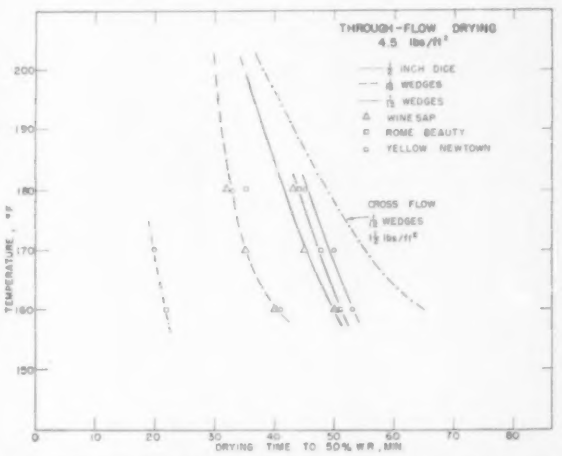

Figure 5. Through-flow drying-rate curves for apple pieces dried to 50% weight reduction for dehydrofreezing.

Sulfur-free dehydrofrozen apples. Sulfur-free apple pieces, treated 3 min in dip solutions containing 1% each of sodium chloride and citric acid, required lower drying temperatures (max 150–160° F) than did sulfur-treated fruit; furthermore, they required blanching without long delay after drying. One important characteristic of this blanched dehydrofrozen product is that the fruit is much firmer than comparable dehydrocanned apples, since the final heat treatment is eliminated.

Reconstitution and use of the product. Dehydrofrozen apples may be used in pie formulas exactly as are frozen or canned apples, except that the double-strength fruit must first be reconstituted with an equal weight of water. After 2 to 3 hr of soaking at room temperature, most of the water is absorbed. Heating shortens the soaking period. To avoid undesirable dryness in pies made from dehydrofrozen apples, the full measure of water must always be pro-

* Blanching is always mandatory when only salt and citric acid dips are used.

vided in the mix, since the rehydration is often completed during the baking operation. Extra water may be added to produce "juicier" pies according to customary practice. The formula and technique to produce pies according to each baker's preference are best determined by trial.

CONCLUSIONS

Use of through-flow drying in dehydrofreezing of apples improves operation by eliminating the need for maintenance of high humidity in the dryer and by increasing drying capacity 3-fold per unit of drying surface.

Control of initial SO_2 content of apple wedges prepared for dehydrofreezing is readily obtained by adjusting piece size, dip conditions, and hold time. However, since only 3 to 10% of the initial SO_2 content remains in dehydrofrozen apple wedges after processing and baking into pie, levels of SO_2 as high as 400 ppm in the fruit (before drying) can be used safely, if required.

Two important advantages are realized by the blanching of the double-strength fruit prior to freezing: packaging density is increased 25–30%; and tendency toward formation of dark centers during defrosting of products that have been insufficiently penetrated by SO_2 is eliminated.

Nonsulfured dehydrofrozen apples may be produced from fruit treated with salt and citric acid, but drying temperatures must be lower, and the double-strength fruit must be blanched before freezing.

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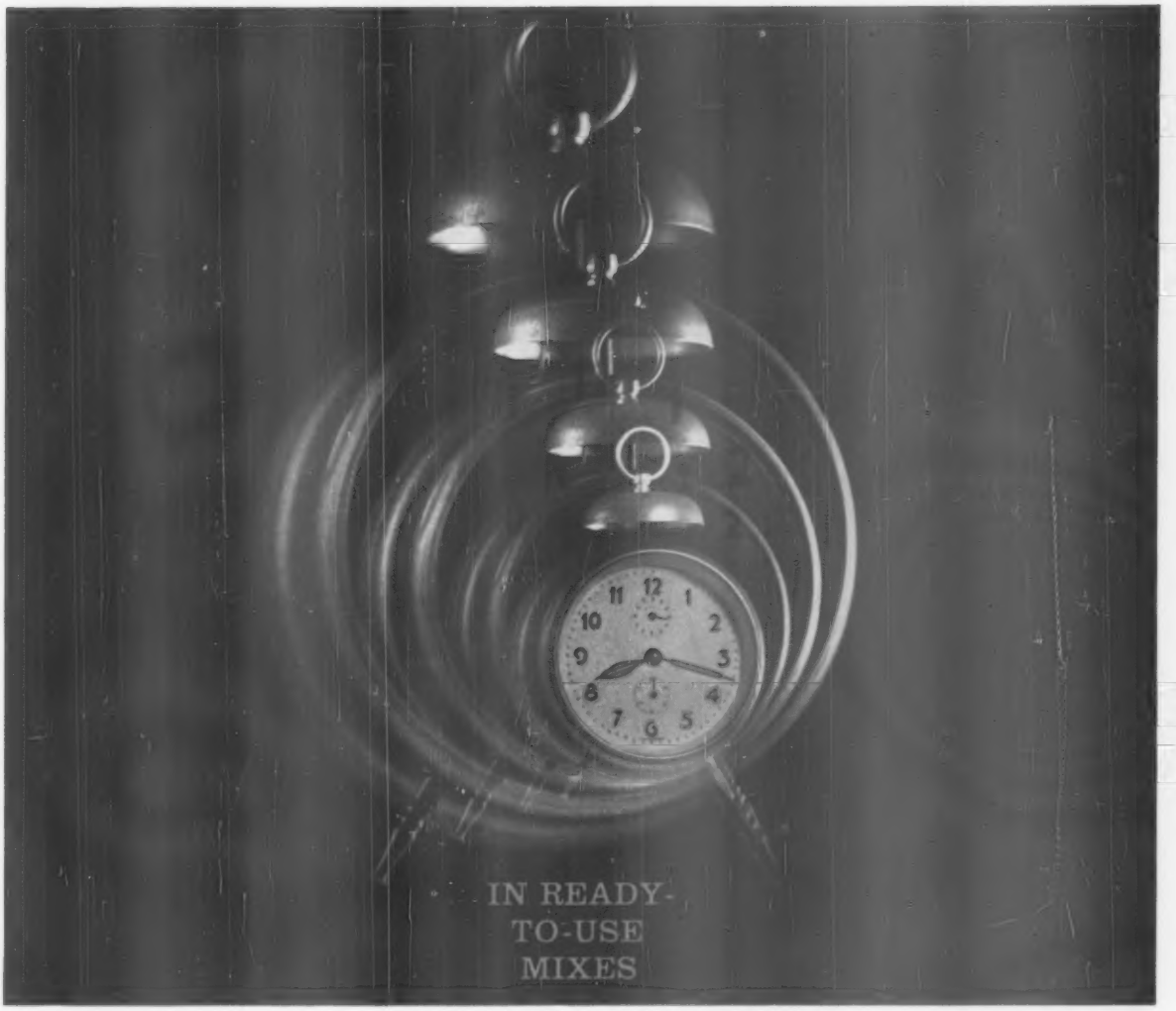

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Notes and Letters

Recent Developments in Foam-Mat Drying*

METHODS FOR MAKING fruit and vegetable juice powders have been under study for some years at the Western Regional Research Laboratory of the U. S. Department of Agriculture. Vacuum puff drying and spray drying have both been studied extensively *(1, 2)*. The most recent development is foam-mat drying, first reported last year. Foam-mat appears to offer advantages over other available methods and is being studied intensively with a view to putting it on a practical production basis.

Many liquid foods, when converted to stable foams, can be dried rapidly in air to yield instant powders *(4, 5)* of good quality. The rapid drying is due to moisture movement by capillarity in the liquid films separating foam bubbles. (See Figure 1). Instant reconstitution results from retention of the honeycomb structure in the dry solid. (See Figure 2.) Suitable foams are made possible by the use of small amounts of edible stabilizers.

Foam stabilizers. The most successful foam stabilizers found in our studies are solubilized soya protein, albumin, sucrose fatty acid esters, and glyceryl monostearate. The soya protein or albumin may be used as 10% water solutions added to the cold food before whipping. Sucrose monostearate can be dissolved in warm ethyl alcohol and used in the same way. The most versatile stabilizer, glyceryl monostearate (GMS) is particularly dependent on proper dispersion. Several effective methods of dispersion have been found. If one part of GMS is added to nine parts of 170° F water, and the mixture is violently blended for a few seconds, a stiff emulsion is formed. If this emulsion is kept at 120°–130° F, it remains dispersible for several days. The emulsion then can be added to the cold food just before whipping to insure a stable foam. Another method of GMS dispersion involves warming the fluid food to 170° F, mixing in the solid GMS in the absence of air, and cooling the mixture to room temperature. Foams can then be produced by whipping this mixture, or a dilution of the mixture with the original food, in the usual way. For most products 1% stabilizer on the dry basis is enough. If the liquid has a low consistency, and especially if it contains no suspended solids, relatively more stabilizer is needed.

About 5 minutes' beating with a motor-driven wire whip produces good foams from the proper ingredients. On a larger scale, the food mixed with stabilizer can be pumped to a tee, where compressed gas is introduced, and then passed through a closed mixer. This method has the advantage of facilitating the use of gases other than air.

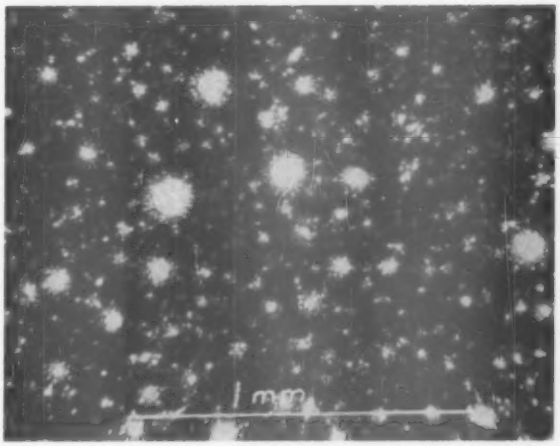

Figure 1.

In the original trials of foam-mat drying *(4)*, the foams were spread on a Teflon or Mylar coated belt in ⅛-inch layers and conveyed through a warm air stream. Most foods required about 60 min in 160° F air to dry to 2% moisture. Under these conditions air velocity and humidity had no appreciable effects on the time required. The limiting process was the transport of water within the product to a free surface at which it could evaporate. Therefore, steps were taken to reduce the mean distance to evaporative surfaces.

The foam was extruded in 1/16-inch to ⅛-inch diameter spaghetti-like strips onto the belt. Drying rate was augmented by heaters under the plate supporting the belt. These changes reduced drying time

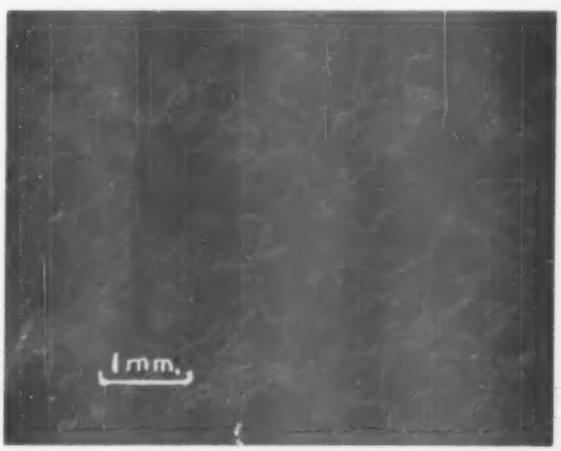

Figure 2.

* Presented at the Twentieth Annual Meeting of Institute of Food Technologists, San Francisco, California, May 17, 1960.

to about 15 min. The dry product was difficult to remove from the belt in some cases, and it was not possible to load the belt very heavily. Nevertheless, this form of dryer is satisfactory as a sample maker and is so used at the Albany, California, laboratory. About 0.1 lb per hr of product can be expected from each square foot of active belt surface used.

The crater technique. We have more recently devised a method which has resulted in a very considerable improvement. This variation in foam-mat drying has been called the crater technique.

In the new method, a layer of foam is spread on a perforated metal tray. A controlled air blast is directed through the tray from below in such a manner that the foam in and above the perforations is spread aside but not splattered off the tray. (See Figure 3.) Drying air is then passed through the perforations from the bottom until the cratered layer of foam is dry.

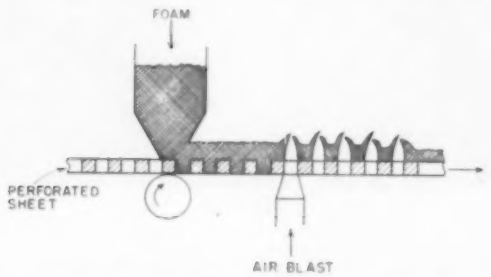

Figure 3. Detail of cratering technique.

Foam-mat drying by this method has several advantages. Because of the large surface exposed to the air stream, most of the water is removed from the product in a very short time. The dried product can be readily doctored off the trays and the trays can be returned to the cycle without washing. The durability of trays is better than that of the belt previously used.

A workable set-up for foam-mat drying by the new method is easy to design. Several practical schemes have been suggested that would permit continuous and automatic loading of trays, conveying them through a dryer, removing the dry product, and recycling the trays to the feeder. About 0.5 lb of product per hr per active square foot of tray area installed can be expected from the proposed systems.

In the specific example of the new technique shown in Figure 4, flat 16-gage aluminum sheets, commercially perforated with $\frac{1}{8}$-inch holes on $\frac{3}{16}$-inch centers, were used as trays. This arrangement gave 40% open area. The trays were loaded with a $\frac{1}{8}$-inch layer of foamed 30% tomato paste. After loading, the trays were moved across a slot through which air was moving at 150 ft per sec. This air stream cleared each hole and produced craters in the foam on the upper side. The trays were then moved through the dryer. Air was passed at 3 ft per sec in a direction parallel to the movement of the trays, passing through each tray from the clean to the loaded side. The dry air at

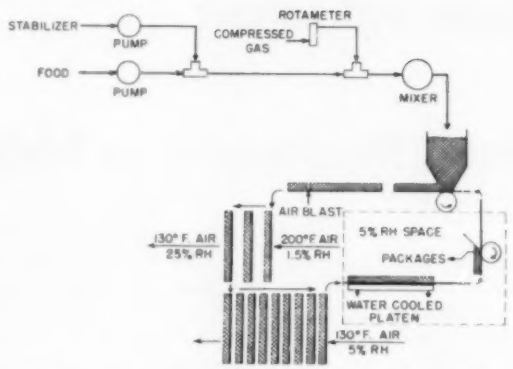

Figure 4. A scheme of crater foam-mat drying.

200° F flowed first through the wettest tray and then through the preceding two trays in order. The pressure drop per loaded tray was less than 0.1 inch of water. On leaving the driest tray, the air had been cooled by the tomato foam to about 130° F and raised to 25% relative humidity. At this point the tray was moved to a countercurrent section in which dry air at 130° F flowed at 2 ft per sec through the driest tray and on through the following wetter trays. The product containing 2% moisture was doctored off the trays and packed.

The main, or concurrent, dryer section removed 80% of the moisture in 3 min. Product quality is maintained by keeping product temperature low and exposure time short. Furthermore, increasing air humidity prevents damage from local overdrying of the surface layer in the concurrent stage.

In order to achieve a moisture content satisfactory for packaging, the final product was exposed to a slow stream of fresh warm air in the countercurrent stage for 9 min. In this stage, quality loss is avoided by the use of relatively low temperatures. Use of dehumidified air for drying is unnecessary for most products, although cooling and packaging should be done at a relative humidity below 10%.

Applications numerous. The foam-mat process can be applied to numerous commodities, with minor modifications of method. Storage life of products, however, has not been determined under various practical conditions.

Orange juice can be foamed with GMS using the warm emulsion technique. The 55–65% solids concentrate is preferred as a starting material. The dry powder has a fresh unburned flavor and odor. When good orange oil enclosed in amorphous sugars is added to the product, a very good juice is produced on reconstitution *(6)*. Less than 10% of the ascorbic acid is lost in the drying step.

Tomato paste, preferably with 30% solids, can be foamed with GMS, using the warm emulsion technique. Instant tomato powder free of burnt flavor and odor can be made by the crater method.

Pineapple juice concentrate of 40% solids content is foamed with the help of modified soya protein solutions. The product has desirable properties on rehydration.

To dry white potatoes by the foam-mat process—potatoes are peeled, sliced, and blanched for one hour at 190° F. They are mashed uniformly, and some water is added to reduce consistency. The GMS warm emulsion is added and the foam-mat process carried out as usual. The solid has a fairly low density and reconstitutes instantly even in cold water to mashed potatoes free of pasty texture.

Various baby foods, including pear puree, green beans, sweet potato, and chicken soup, have been dried from the single strength condition. For this purpose, GMS was used with the warm emulsion and warm product techniques.

Coffee extracts of 30% solids can be foamed and dried with the help of sucrose monostearate. Only 0.2% SMS on a dry basis should be used. The resulting powder has good aroma and is also instant in ice water.

Prune, apricot, and strawberry purees, and applesauce, can be foamed by the GMS warm product method. A fruit processor could use existing tunnel dryers for the purpose of drying the foams. Polyethylene film has been stapled to plywood panels which were cut to fit a standard tunnel dryer. The foams were spread on the polyethylene in a thin layer by a simple feeder. This is given only as an example of the adaptability of the process to special conditions.

Pectin, pectin-sugar, and starch have been dispersed in water and foamed with GMS warm emulsion. When dried, these powders have been found much more readily dispersible, although more aerated, than the original materials.

Grape, lemon, apple, and prune concentrated extracts and molasses have been foamed with GMS using the warm product method or with modified soya protein. These powders have been satisfactory except for their tendency to cake. Prune whip powder has been produced, relying on the albumin content for foam stability. Peach puree can be foamed with albumin.

The foam-mat method has been made more practical by improvement in methods of foam stabilizing and by an improved drying technique. Promising applications include orange, tomato, pineapple, potato, baby foods, whole milk, coffee, apricot and prune purees, apple sauce, and instant carbohydrate products. Work on adaption of drying techniques to obtain the best quality in each commodity and on storage stability is continuing.

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L. F. Ginnette, and G. S. Williams
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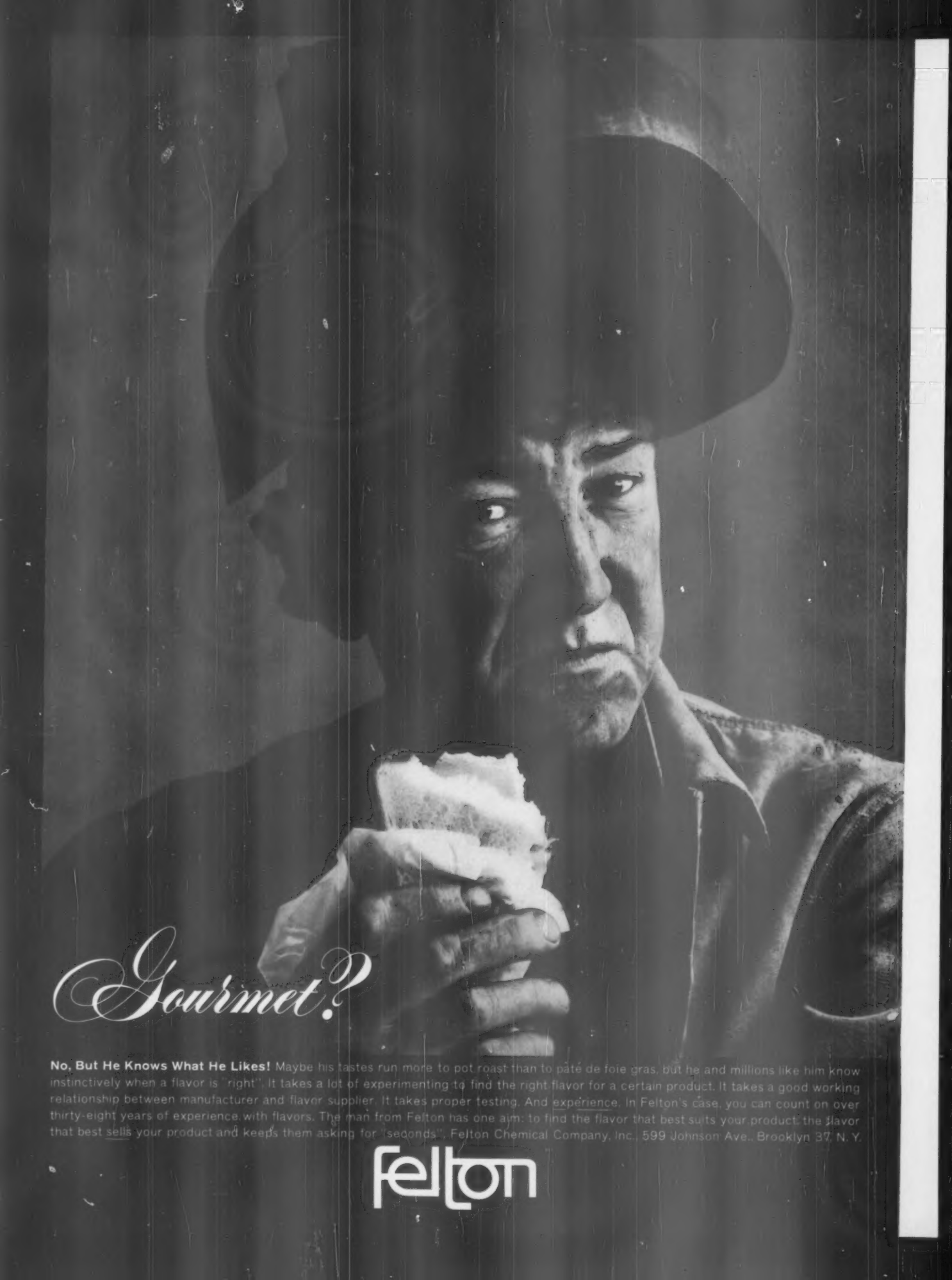

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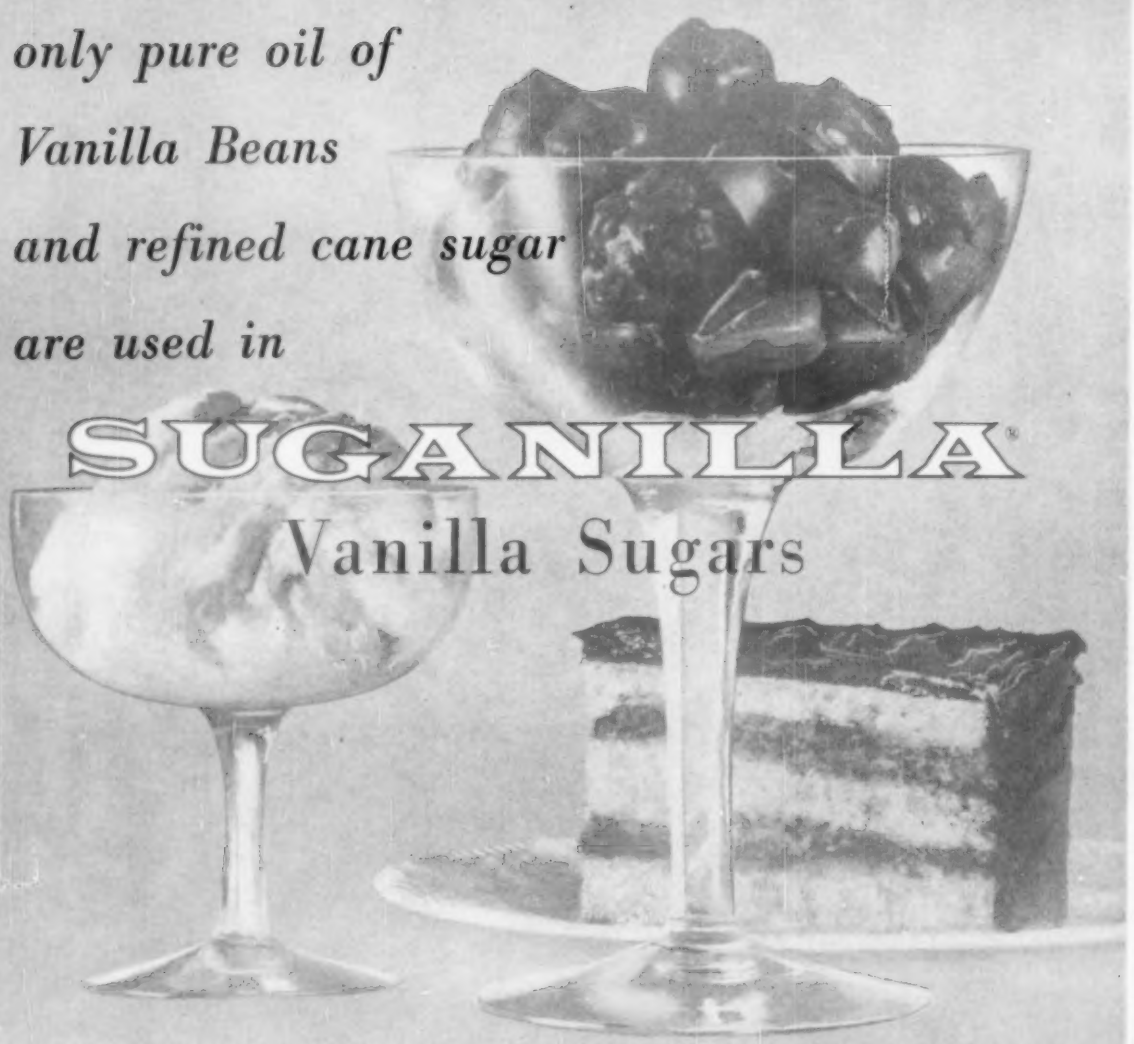

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Unpublished citation: Smith, John. 1947. Unpublished data. University of California, Davis.

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2. **Abbreviations.** The following are acceptable abbreviations:

ampere	amp
Angstrom units	A
atmospheres	atm
average	av
avoirdupois	avdp
boiling point	bp
Centigrade	C
centimeters	cm
cubic centimeters	cc
cubic millimeters	mm^3
dextro	*D-*
effective dose, 50%	ED_{50}
et alii	*et al.*
Fahrenheit	F
figure	Fig.
foot	ft
gallon (U.S.)	gal.
gram(s)	g
gravitational constant	G
hour	hr
inch	in.
kilocalories	kcal
kilograms	kg
least significant difference	LSD
lethal dose, 50%	LD_{50}
levo-	*L*
liters	L
logarithm (common)	log
logarithm (natural)	$\log_e$
melting point	mp
meter	m
micrograms	μg
micron	μ
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milliseconds (time)	msec
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molecular weight	mol wt
normal	*N*
ounce	oz
parts per million	ppm
percent	%
pound	lb
refractive index	n_D
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(Continued from page 12 preceding technical section)

cated they would not use cake mix. (Interestingly enough, the proportion of homemakers who would not use cake mix decreased from the age group under 30 to the group 40–49 years old, and then increased as age increased.)

More than 90% of the consumers who would serve angel food cake would be willing to serve a cake made from a mix at either a church supper or to the husband's boss. And more than 96% would be willing to serve an angel food cake made from mix to their family. The indication is that the conflict between self-esteem or status values and convenience may, over time, be resolved in favor of the convenience value. This is particularly true of an item like cake, since the homemaker can add her own touch through a special type of frosting or decoration. It is also probable, however, that the importance of convenience is so strong in the minds of some homemakers that they are quite willing to inform their guests that the cake was made from a mix.

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INDUSTRY BULLETINS

Tape programming, utilized for in-process stream analysis by chromatography, is described in a four-page bulletin now available from Mine Safety Appliances Company, Pittsburgh. The literature features a new gas chromatograph that is believed to be considerably more accurate than conventional mechanical cam timers. In addition, the unit is said to have a higher degree of stability in column temperature, and permits either bar graph, spectrum, or manual chromatographic presentation. Copies of the bulletin—No. 0714-5—may be obtained by writing: Mine Safety Appliances Company, 201 North Braddock Avenue, Pittsburgh 8, Pennsylvania.

A new bulletin from The Pfaudler Co. describing a wiped film evaporator illustrates how the ultrathin, uniform film produced by mechanical wiping of the evaporating surface results in substantially higher

volume and quality production than can be obtained with standard evaporating equipment. The wiped film evaporator is designed for use with products that are heat sensitive, highly viscous, or low in thermal conductivity. Highlighted features of the unit discussed in the new bulletin include: (1) slotted wiper blades which accelerate the movement of even highly viscous materials down and off the heated evaporating wall and prevent channeling and formation of "product curl" in front of the wipers, (2) short contact time from a fraction of a second for free-flowing materials to a few seconds for highly viscous ones. The new bulletin contains a cut-away view of the unit showing the relation of heating jacket, wiper blades, entrainment separator and internal condenser. Specifications for 12″ and 36″ diameter models are included as well as a brief description of evaporating cycle. Copies of Bulletin 991 may be obtained by writing to The Pfaudler Co., 1120 West Avenue, Rochester, New York.

A new twelve-page brochure published by Industrial Nucleonics Corporation describes the principles upon which continuous, non-contacting measurement of fluids in pipes is achieved. Titled "Accu-Ray Continuous On-Stream Composition Analysis," it outlines how AccuRay Composition Analysis Systems use radioisotopes to detect changes in specific gravity, percent solids, concentration, or related quantity of materials conveyed in pipes. Also included in the brochure are sections devoted to the economic justification for this type of equipment, descriptions and drawings of the system components, and applications data. To obtain a copy, write for Bulletin CA-860, Industrial Nucleonics Corporation, 650 Ackerman Road, Columbus 2, Ohio.

A new 19-page publication listing several hundred compounds exhibiting fluorescent characteristics is now available as a guide to identifying solutions through their fluorescent properties. The publication lists compounds, activation and fluorescing wavelengths, pH values, and ultimate sensitivities [concentration in micrograms-per-milliliter producing a useful (10% full-scale) meter deflection at maximum sensitivity]. The list is available without charge from the American Instrument Co., Inc., 8030 Georgia Avenue, Silver Spring, Maryland.

A new accessories bulletin for Beckman DK Spectrophotometers has been published by the Scientific and Process Instruments Division of Beckman Instruments, Inc., Fullerton, California. Accessories described in the brochure adapt DK Spectrophotometers to the requirements of such analyses as flame photometry, fluorometry, reflectometry, spectroradiometry, colorimetry, solid phase studies, reaction rates studies, and turbidity observation.

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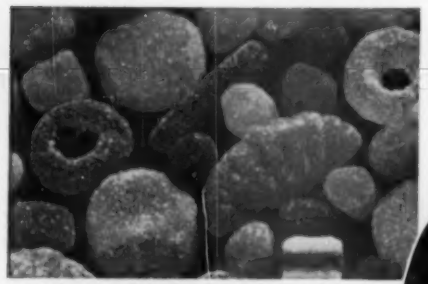
Industry News

Claricol, a semi-fluid crystal inhibitor for use in extending the Cold Test of edible and non-edible oils and oil products; and, for use in winterizing these oils, is announced by Beacon Chemical Industries, Inc. Beacon claims that use of Claricol assures that salad oils, cooking oils, mayonnaise, and salad dressings remain crystal-free longer under colder conditions, and does not affect flavor, stability, color, or smoke point. Addition of 0.03 to 0.04% Claricol to cottonseed salad oil quadruples the AOCS Cold Test on a typical oil according to Beacon. Experimental samples requested on company letterheads are available from Beacon Chemical Industries, Inc., Richdale Ave., Cambridge 40, Mass.

A new model, the Cowles Dissolver Model 5-VTV, has been added to the Morehouse-Cowles, Inc., line of equipment for mixing, dispersing and deagglomerating. Basic new feature of the 5-VTV is the variable speed drive system with a range of from 1800 to 5400 rpm and allowing for quick changes of speed while in operation. Designed for small production, pilot plant operations and R & D facilities, the 5-VTV is said to be adaptable to critical dispersing and mixing problems over a wide range of processes and materials. It is also said to be capable of handling a wide range of viscosities up to 50,000 centipoises in 5 to 40 gallon batches. For full information on the Model 5-VTV or other Morehouse-Cowles equipment, write Morehouse-Cowles, Inc., 1150 San Fernando Road, Los Angeles 65, California.

The Diversey Corporation announces a portable, compact spray cleaning unit for storage tanks. The unit can be installed in a matter of seconds, and cleaning takes no more time than with permanently installed units, according to the company. D-Spra 700, as the unit is designated, weighs less than 15 pounds and is completely adjustable for various size openings. Diversey also claims that it has the effective vertical and horizontal range required to clean the vast majority of storage tanks, while delivering a high volume of cleaning solution at relatively low pressure. For more information about the D-Spra portable spray cleaning unit, write the Diversey Corporation, 1820 W. Roscoe Street, Chicago 13, Illinois.

Recently introduced is a new instrument capable of exciting, measuring, and recording phosphorescence of compounds. The instrument, the Aminco-Keirs Spectrophosphorimeter, permits excitation of compounds and measurement of resulting phosphorescence



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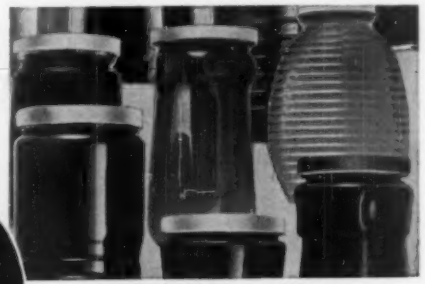

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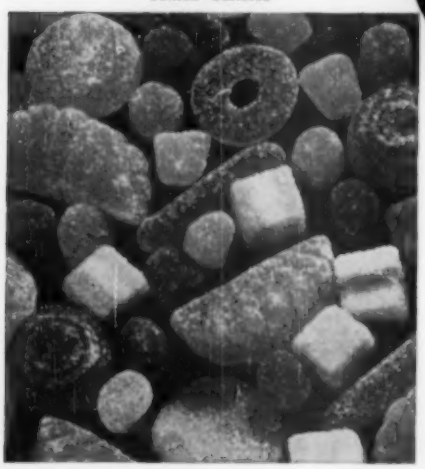

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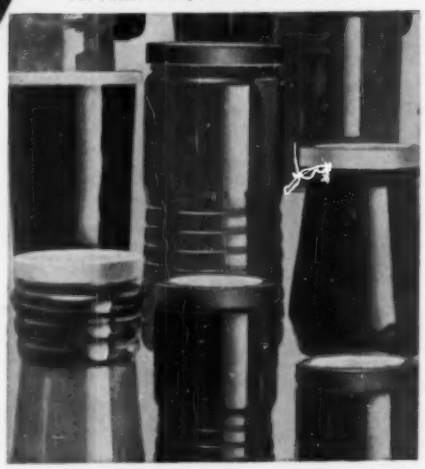

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throughout the ultraviolet and visible regions. Theory of operation is based on the fact that innumerable organic molecules phosphoresce when excited by ultraviolet light, provided these compounds are dispersed in suitable media. These phosphorescences are unique in regard to their spectral frequencies, lifetime, and spectral-vibrational patterns. Consequently, recordings may be used to identify various components in compounds of unknown composition. The instrument also quantitatively analyzes phosphorescent compounds according to Aminco. Bulletin 2334, free upon request from the American Instrument Company, Inc., 8030 Georgia Avenue, Silver Spring, Maryland, provides full information and applications of the Spectrophosphorimeter.

Bausch & Lomb has announced development of a new Serum Protein Meter which it claims will provide accurate protein analyses in as little as one-tenth the time required by chemical methods. Analyses for protein in serum can be run in three steps: (1) Sample is centrifuged and serum placed in one or two sample cells. (2) Distilled water is put into second sample cell and placed on instrument, which is then "zeroed." (3) Sample cell containing serum is set on protein meter, which reads, directly, protein grams per 100 mm. 2.5 ml of serum are needed for accurate determination, and no temperature controls are required other than equal temperatures for both sample and distilled water. Readings are referred to the index of refraction of water. The instrument's eyepiece reticle contains two scales: one provides readings in serum protein directly to 0.1 gram (range: 0 to 12 grams per ml), the other, reading in refractive index difference, covers a range of 0.0234, and is useful for making independent correlations between refractive index and other properties of solutions. A pair of special glass sample cells with plane-parallel bottoms is supplied with each instrument. These eliminate direct contact with the serum, thereby reducing chances of sample contamination. The serum can be recovered for further analyses, and the sample cells cleaned by standard lab methods. Retail price for the B&L Serum Protein Meter is $175. Further information is available by writing to Bausch & Lomb Incorporated, Rochester 2, New York, requesting bulletin #D-2013.

A new recording differential refractometer offered by Waters Associates, Framingham, Massachusetts, enables, according to the manufacturer, measurement of extremely small differences in the index of refraction of liquids for process monitoring, quality control, and pilot plant studies. This new Differential Refractometer measures index of refraction changes as small as 0.0000007 index of refraction units, and requires no more space than a strip chart recorder. The analyzer section is mounted within a standard strip chart recorder, thereby combining an analyzer and recorder in one unit. Other features claimed are: full scale ranges as narrow as 0.0003 and as broad as 0.16 index of refraction units; zero drift of less than 0.000003 refractive index units per 24 hours; batch or continuously flowing sample analyzation with the instrument insensitive to changes in both ambient temperature and sample temperature. For complete description and details, write: Waters Associates, 45 Franklin Street, Framingham, Massachusetts.

Beckman Instruments announces its new Model 930 Air Comparison Pycnometer, which is designed for rapid measurements of volume, density, and porosity of irregular, powdered, or porous solids. It requires no liquids, gas pressure determination, or temperature control according to Beckman, and it is said to provide true volume measurement for specific gravity and density in such applications as mineral identification, chemical mixture and determination, and porosity determinations of sintered and porous materials in less than one minute. For further information, write to the Technical Information Department, Beckman Scientific and Process Instruments Division, Fullerton, California, for a copy of Bulletin 786.

A new type of machine for high-precision continuous weighing of loose, free-flowing granular solids has been developed by The Exact Weight Scale Company, Columbus, Ohio. Operation of the fully automatic machine is based on accurately net weighed quantities dumped at uniform time intervals. When placed over a product stream a precision scale, with over-and-under indicator, weighs precise amounts of the additive in a net weigh hopper. An air operated mechanism then dumps the additive into a small, secondary hopper which in turn, feeds the additive into a vibratory feeder. From the vibratory feeder the additive is introduced into the continuous processing line in a uniform even flow. The machine permits handling of products in quantities from 1 oz. to 3 lbs. and 3 lbs. to 10 lbs. For additional information on continuous weighing machines and systems, write to The Exact Weight Scale Company, 538 East Town Street, Columbus 15, Ohio.

A new Digital Refractometer offered by Waters Associates, which makes use of a null meter and direct digital readout to measure index of refraction changes as small as 0.0000005 index of refraction units is now available. The instrument can be set such that 1000 units on the digital readout is equivalent to a refractive index range as narrow as 0.0005 R.I. or as wide as 0.2 R.I. Model 107A is provided for research investigations in liquid chromatography, molecular weight measurements, ion exchange studies and pilot plant evaluations of new products. The research model is usually provided uncalibrated and

is priced at $695.00. Model 107B is provided for quality control of batch or continuous processes. It is factory calibrated for a particular application and is priced at $900.00. For information on these digital readout refractometers, write: Water Associates, 45 Franklin Street, Framingham, Massachusetts.

MECCO Instruments introduces a new Colormaster Differential Colorimeter. The Colormaster features an adjustable zero attachment for standardizing the instrument. In addition, it features the highest accuracy and precision of any type of differential colorimeter commercially available, according to MECCO. Readings are given in terms of green, red and blue reflectance values, or X, Y, and Z. Computations to L, a and b may be made with charts or the Colormaster computer. The Colormaster is designed to measure color as required in color matching, product specification, or studying color fastness, and achieves the highest precision where measurements are between a test sample and a standard color. For complete information write for Bulletin No. CM-1200 to: Manufacturers Engineering & Equipment Corp., York and Sunset Lane, Hatboro, Pennsylvania.

PERSONNEL

During the month of October 1960 Dr. Anthony Lopez, Professor of Food Technology, Virginia Polytechnic Institute, spent two weeks in Spain at the invitation of the Ministry of Commerce of that country. The purpose of his trip was to give a series of seven lectures on different food technology subjects. The lectures were given in the cities of Seville, Murcia, Valencia, Logrono, and Madrid, all food processing centers. The invitation was extended by the Spanish Government as part of a program recently initiated by that government to promote the development of the food industry and to improve the quality of Spanish processed foods. In Spain Dr. Lopez visited several fruit and vegetable processing plants, universities, and research

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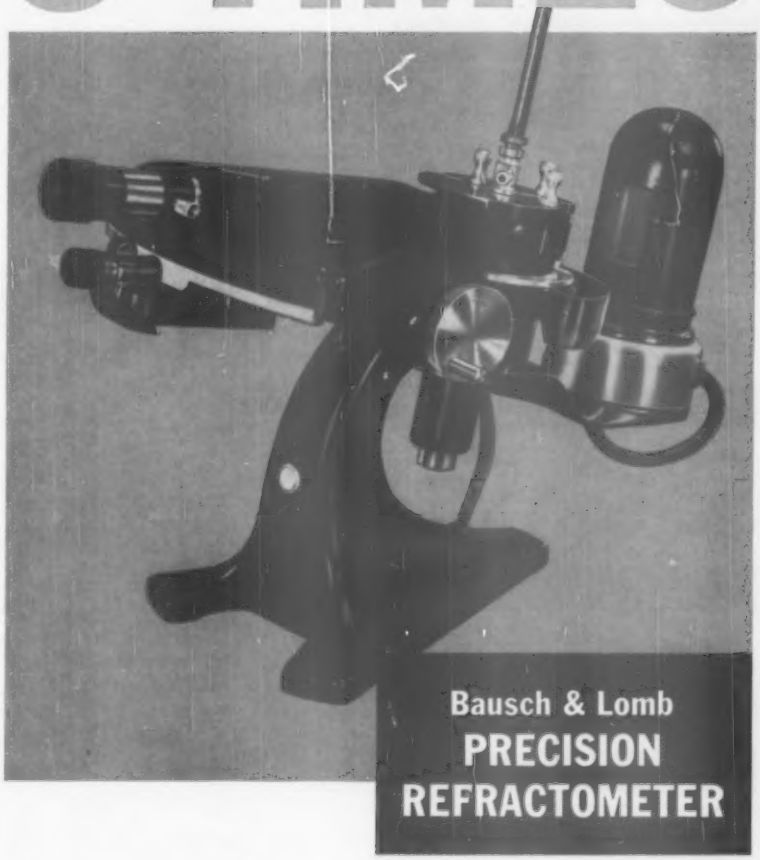

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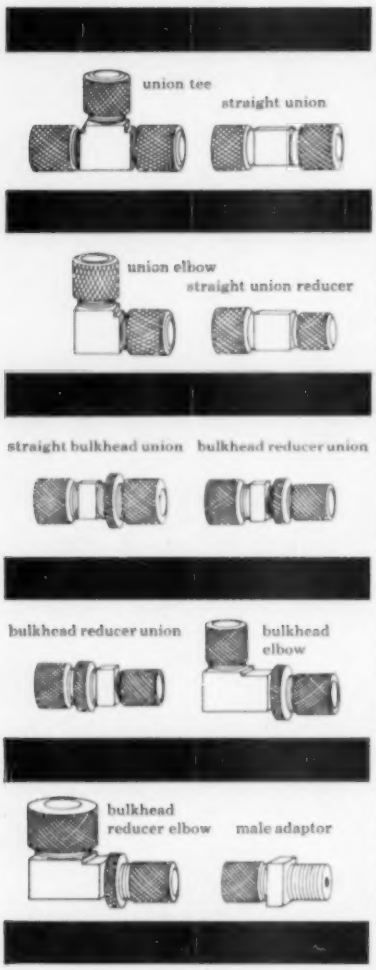

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centers. His visit to the newly established School of Food Technology of the University of Valencia was especially noteworthy. This school offers a good graduate program in food technology. It is the first one and only one of its kind in Spain. The school is headed by Dr. Eduardo Primo Yufera; three of its five staff members have done graduate work in the United States.

Ernest Wolf

Mr. Ernest Wolf has been promoted to manager of chemical sales for the international division of Baxter Laboratories, Inc. He was formerly coordinator of commercial development for Baxter's Wallerstein Company division, and came to Baxter in 1959 from Olin Mathieson Chemical Corporation where he was a technical representative with the energy division. Mr. Wolf received a B.S. degree at Queens College, Flushing, N. Y., an M.S. degree in organic chemistry at Purdue University and an M.B.A. degree from the University of Buffalo.

J. F. Farley

The Independent Grocers' Alliance has named **John F. Farley** director of its new Quality Control Department. Mr. Farley will be in charge of grocery product procurement, will develop new grocery items and will establish quality control practices for all IGA products. He formerly did new product development work for Libby, McNeill & Libby and for Topco Associates, Inc. He received a Master's degree in Food Technology from Purdue University, where he was a teaching fellow for two years and an instructor for one year.

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SITUATIONS WANTED

Unless otherwise specified, particulars on the following individuals may be obtained by writing: Executive Secretary, Institute of Food Technologists, 176 W. Adams St., Chicago 3, Ill. Request by box number.

AVAILABLE: CEREAL CHEMIST and FOOD TECHNOLOGIST—twenty years of varied and responsible exp. in products control, research and development—excellent background in commercial baking and baking technology—seeks promising position in Product Development and/or Technical Service. REPLY BOX 819.

Recent graduate with Ph.D. in Food Science desires position in Product Development, Quality Control, Packaging and Preservation of Poultry Products or related fields. Salary $8,500. REPLY BOX 825.

FOOD TECHNOLOGIST M.S. Desires responsible position as Director Quality Control. Ten years diversified foods experience in production, research, management, and sales in vegetable canning and meat industry. Salary $9,500. REPLY BOX 829.

New Ph.D. in food technology desires product development, technical service, or industry research position. Spent a short time as consultant in product development and industry research. Salary, $10,000. REPLY BOX A-625.

Individual with Ph.D. in bacteriology desires post doctoral fellowship in a university or a similar position in industry. Salary, $7,000. REPLY BOX A-628.

Mature individual with heavy experience in product development, production, engineering, and quality control desires production and laboratory supervision position. He holds an Sc.D. in colloid chemistry. Salary, $9,000. REPLY BOX A-634.

Industry research, product development and academic research are respective areas of interest to young, available, Ph.D. food technologist. Salary, $8,000. REPLY BOX A-636.

Fruits, vegetables, and cereals interest Ph.D. food technologist who desires product development, industry research, or technical service position. Salary, $9,000. REPLY BOX A-611.

Industry research position in food technology desired by Ph.D. Experience includes eight years in industry research and three years in quality control. Salary, $11,000. REPLY BOX A-637.

Heavy experience in product development, quality control, and technical service are characteristics set forth by Ph.D. in chemistry who desires to work with flavors, cereals and baked goods. Salary, $10,000. REPLY BOX A-638.

B.S. in biochemistry desires lab and/or panel research, or statistical quality control manager position. Product preferences include edible nuts, confections, and deep fat fried products. Salary, $8,500. REPLY BOX A-106.

Research and development and quality control interest man with ten years experience in the latter. Product preference lies within the area of dehydrated and freeze dehydrated foods. Salary, $8,400. REPLY BOX A-107.

Mature individual with a preference for and experience in fruit and vegetable production and procurement wishes position involving field work in processing crops. Also interested in extension education. Salary, $7,000. REPLY BOX A-108.

Quality control, packaging, and preservation of poultry products interest new Ph.D. in food science. Position preferences also include product development and industry or academic research. Salary, $8,000. REPLY BOX A-639.

Food technologist or lab technical position dealing with juices or cereal products desired by graduate with major in agricultural chemistry. REPLY BOX A-1.

1950 graduate with B.S. in food technology desires position in product development, production, technical sales, technical service, packaging, or quality control. Salary, $8,000. REPLY BOX A-2.

Recent graduate with B.S. in food processing desires R&D position working with fruits or vegetables. Product development, production, or industry research preferred. Salary, $6,500. REPLY BOX A-5.

Experienced man desires quality control, product development, or production position in the area of vegetables and fruits. Salary, $12,500. REPLY BOX A-8.

1954 food technology graduate interested in quality control, research, or production management position. Interest range also covers technical service and packaging. Salary, $9,000. REPLY BOX A-14.

Young food technology graduate interested in either technical sales position, or product development or technical service oriented toward management. Product preference is fruit and vegetables. Salary, $6,800. REPLY BOX A-17.

Meats, fats and oils, and feed interest man who desires position as food chemist or food technologist. Salary, $7,500. REPLY BOX A-20.

1956 graduate with B.Sc. in Home Economics indicates she is interested in a product development or food promotion position. Salary, $6,200. REPLY BOX A-25.

W. W. II veteran with five years experience in packaging seeking position in that field, purchasing, or engineering. Product preference is frozen foods. Salary, $9,000. REPLY BOX A-28.

Quality control position with primary emphasis on frozen foods desired by 1955 food technology graduate. Salary, $5,800. REPLY BOX A-30.

Cereal chemist graduate desires executive technical or managerial position. Interests are product development, production, technical service, packaging, and quality control. Salary, $20,000. REPLY BOX A-37.

POSITIONS AVAILABLE

Unless otherwise specified, particulars on the following positions may be obtained by writing, including the company name of your current employer: Executive Secretary, Institute of Food Technologists, 176 West Adams Street, Chicago 3, Illinois. Request by box number.

FOOD TECHNOLOGIST. B.S. Degree required. For work in heat processing and technology of canned foods. Technical consultation and service work involving some travel. No experience necessary. Eastern location. REPLY BOX 826.

Frozen bakery products company in East has opening for recent graduate to do Product Development and laboratory work. Training in food chemistry, bacteriology and biochemistry desirable. State salary requirements, draft status. Excellent working conditions and future opportunities. REPLY BOX 827.

DIRECTOR–RESEARCH
SOUTH AMERICA

Large international meat processing company looking for Food Technologist or Chemist Ph.D. with research experience in the meat industry, plus executive ability to manage Food Research and Development Laboratory in in Buenos Aires, Argentina. Salary open. Send résumé. REPLY BOX 828.

RESEARCH CHEMIST
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Need young college graduate with degree in food chemistry, food technology or cereal chemistry and several years experience to work in research and new product development. Good opportunity to grow into responsible position and fringe benefits include profit sharing. Salary open. Write BOX 831.

ASSISTANT PROFESSORSHIP IN
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Position available in teaching and research in poultry products technology, with research emphasis on poultry meats, but can include egg quality studies. Ph.D. required. Reply with résumé of qualifications to: M. S. Cover, Department of Animal and Poultry Science, University of Delaware, Newark, Delaware, Box 830.

FOOD TECHNOLOGIST

Modern, growing food plant in North Jersey requires an experienced Research Technologist to develop new food processes. Under minimum supervision, the man we seek would tackle technical problems requiring the application of advanced knowledge. Considerable ingenuity and initiative to adopt new methods are needed, plus ability to direct activities of other professionals.

We also have an opening for a Food Technologist with consumer testing experience to carry out product testing programs with outside organizations. A degree and minimum of 5 years experience in specific field required.

Salary commensurate with training and experience. Opportunities for growth unlimited. Please submit résumé with salary requirements. All replies held confidential and all will be answered. BOX 830.

ASSISTANT PROFESSORSHIP IN FOOD TECHNOLOGY

Biochemist with interest in Food Technology problems needed for basic research on composition or metabolism of plant or animal products. Ph.D. required. Reply with résumé of qualifications to: J. H. McClendon, Department of Agricultural Biochemistry and Food Technology, University of Delaware, Newark, Delaware.

RESEARCH FELLOWSHIPS in nutrition or Food Technology leading to a Ph.D. degree in one of several university departments, depending on student's interest. Stipend $230/month and up. Write to J. B. Brown, Director, Institute of Nutrition and Food Technology, Ohio State University, 1645 Neil Avenue, Columbus 10, Ohio.

RESEARCH KITCHEN PRODUCT DEVELOPMENT

Leading national supplier of basic ingredients to the food industry has excellent opportunity in its Research and Product Development kitchen. The company is located in Chicago. The applicant should have 10 years experience in meat processing including curing, smoking, sausage manufacturing, and related meat areas. Should have enough supervisory and organizing experience to direct Research and Development activities. Should be creative and research minded. Excellent salary for the man with the proper qualifications. Reply in detail stating experience and salary required. REPLY BOX 824.

FREEZE DRY ENGINEER

Degree in food or Bio-Eng. (strong in Engineering, Bacteriology and processing of foods) or degree in Chemistry, Bacteriology, Chemical Engineering or Veterinary Medicine or Academician with advanced degree and considerable consulting experience in Freeze-Dry techniques and equipment.

Must have 5–10 years experience. Thorough knowledge of Freeze-Drying techniques and equipment with food, pharmaceutical or veterinary medicine, agriculture or government research industries.

Salary $10,000–$12,000 plus.

Please send résumé to John S. Dickey, Employment & Training Admin., American Sterilizer Company, 2424 West 23rd Street, Erie, Pa.

Food technologist. Midwest location. Technical degree required plus 0-2 years experience. Maintenance of quality and development of new products including coffee, vegetable oil products, glass packs, etc. A non-routine position necessitating willingness to travel. REPLY BOX P-725.

Dairy technologist. Midwest location. Technical degree required plus at least two years experience in grading. Position entails cheese grading and approving purchases of cheese and other dairy products. Individual selected must be willing to travel. REPLY BOX P-726.

Home economist. Midwest location. Home Econ. degree required plus 0-2 years experience. Position entails food laboratory work mainly concerned with taste panel techniques and preparation of recipe food products for evaluation. REPLY BOX P-727.

Product development. Southern location. B.S., M.S., or Ph.D. for product development in frozen and canned seafoods and animal items. Bacteriological and chemical studies involved. REPLY BOX P-728.

Development Bacteriologist. Midwest location. B.S. or M.S. in bacteriology plus one year of industrial bacteriology work on meats. Position entails bacteriological analyses, specifications, and development research. REPLY BOX P-729.

Technologist. Midwest location. B.S./M.S. in chemistry and/or bacteriology for quality control position involving chemical and bacteriological control of raw ingredients, processing parameters and finished product. REPLY BOX P-730.

Midwest location with considerable travel on National basis. An M.A. or Ph.D. in dairy and/or food technology and/or biochemistry required for this technical service position. Experience should include sales and research experience in dairy field. Home office research also involved. REPLY BOX P-302.

Chief chemist, food laboratory. East coast location. M.S. in chemistry or food technology, or heavy experience in baking, dairy and/or packaged goods necessary. Product development and applications research in area of starches, modified starches and water soluble gums. REPLY BOX P-304.

Manager of Food Technology and Development. Western location. Minimum of M.S. or equivalent in food technology or related fields for man who will organize, develop, and direct a food technology, development and service department. REPLY BOX P-305.

Technical assistant. East coast location. M.S. or Ph.D. plus 2 to 5 years experience principally in cereal chemistry required of individual who will assist in technical sales service, follow research, write brochures, approve advertising, etc. Products involved include sanitizing agents, colors, vanillan, etc. REPLY BOX P-309.

Research and analytical chemist. Central states location. M.S. in organic chemistry or equivalent. Experience in pesticide analysis and/or analytical organic chemistry. Person selected will establish an analytical section primarily for pesticide analysis, but involving entire research program. REPLY BOX P-314.

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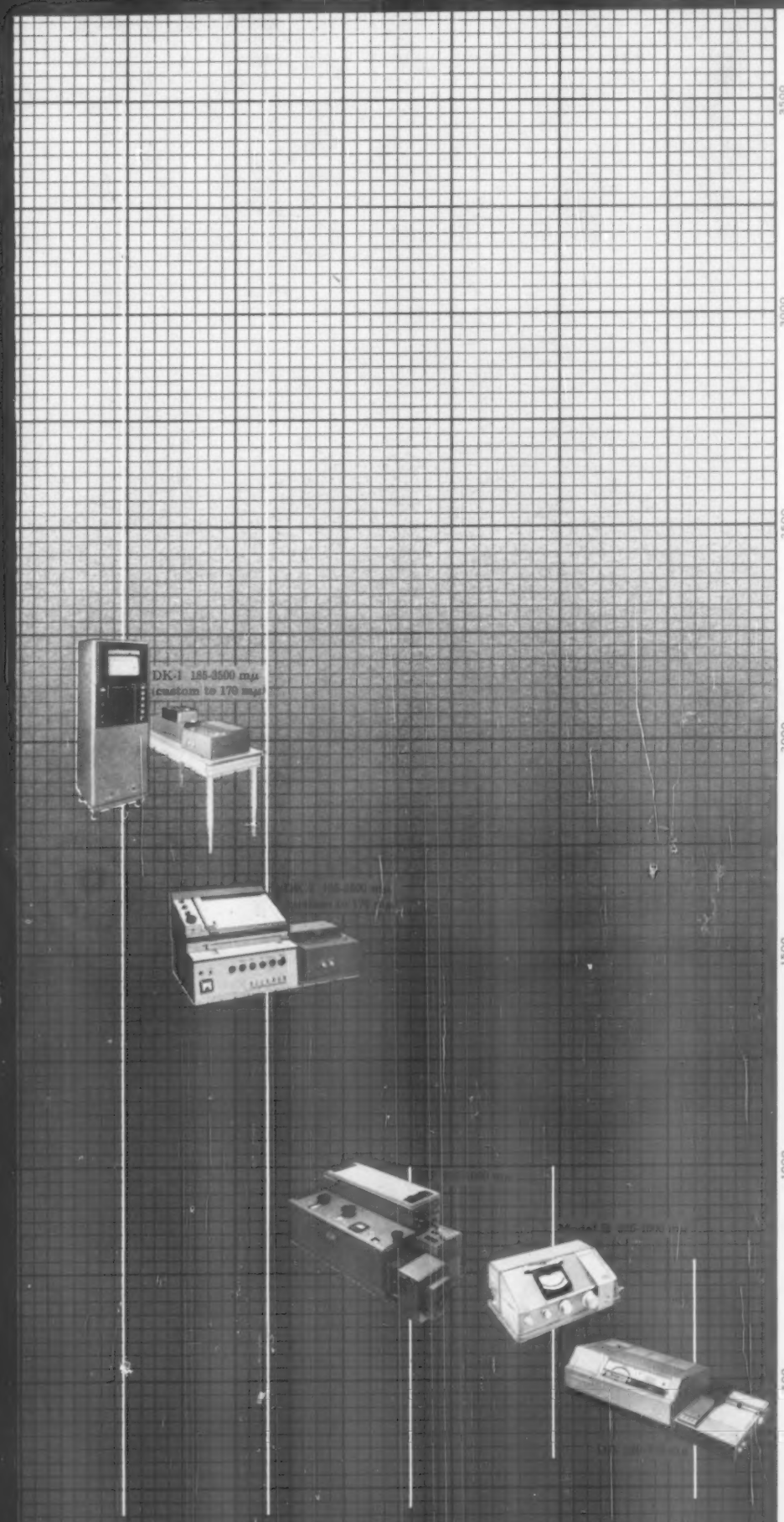

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